①

MODELING THE PAVE LOW HELICOPTER
PILOT CAREER FIELD

THESIS

John C. McKoy
Captain   USAF

AFIT/GOR/ENS/88D-14

DTIC
ELECTE
JAN 1 8 1989
D
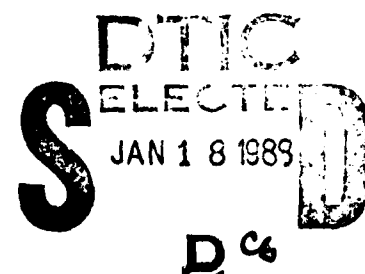
DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

89   1 17 089

DTIC
S ELECTE
JAN 1 8 1989
D Co

MODELING THE PAVE LOW HELICOPTER
PILOT CAREER FIELD

THESIS

John C. McKoy
Captain   USAF

AFIT/GOR/ENS/88D-14

Approved for public release; distribution unlimited

AFIT/GOR/ENS/88D-14

MODELING THE PAVE LOW HELICOPTER
PILOT CAREER FIELD

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

John C. McKoy, B.S.

Captain   USAF

December 1988

Preface

I would like to thank the following individuals for their invaluable assistance:

My advisor, Major Kenneth Bauer, for his guidance, support and interest in both my welfare and my education.

My reader, Dr. James Chrissis, for his helpful editing.

My classmates for their help in getting me through the past year and a half.

My wife, ███████ for having a good sense of humor about this whole thing.

Table of Contents

List of Figures

List of Tables

AFIT/GOR/ENS/88D-14

Abstract

This thesis presents a career model of the USAF Pave Low
helicopter pilot force. A SLAM II computer simulation was
developed to permit experimentation with key decision
variables. Response surface methodology was used to produce
two response equations which, in turn, became goals for a
goal programming model. This model provided optimal values
for the decision variables in order to achieve manning and
experience-level goals.

MODELING THE PAVE LOW
HELICOPTER PILOT CAREER FIELD

I.   Introduction

The Issue

"Low-intensity conflict represents the most probable arena for the application of U.S. military force in the foreseeable future," according to Major Kenneth Page in his article, "US Air Force Special Operations: Charting a Course for the Future." As a result, Congress has directed the USAF to improve its special operations helicopter capability by building up its small force of MH-53 Pave Low helicopters. (Page, 1987:58,66)

However, at the same time, many other USAF helicopters are being phased out of service, resources which in the past have provided flying hours and experience for pilots who would later transition to the more sophisticated Pave Low. Therefore, there is concern that the Air Force may eventually be faced with the prospect of sending primarily new, less experienced pilots to the Pave Low, pilots who have not had the benefit of developing airmanship skills in a less complex helicopter.

Problem Statement

As the Air Force's pool of experienced helicopter pilots

shrinks, sustaining an experienced Pave Low pilot force will become more difficult. AFMPC does not have a model of the Pave Low pilot force to study force sustainment, so they are not able to predict how policies will affect the force.

Research Objective and Scope

The objective of this research is to develop and analyze a model of the 1025N (Pave Low pilot) career field as it will exist after the force reaches full strength in order to examine how to best sustain the pilot force in the future.

This investigation will be limited to Pave Low pilots and copilots, from the time they enter the Pave Low school until they stop flying the Pave Low permanently. It will include the time those individuals spend in career-broadening/staff assignments, assuming they return to the Pave Low cockpit. It will not include other helicopter pilots except as inputs to the Pave Low force.

Key Terms/Acronyms

AFMPC - Air Force Military Personnel Center

MAC - Military Airlift Command

PME - Professional Military Education

PQP - Prior Qualified Pilot

Rated Officer - a pilot or navigator

Rated Supplement - rated officers holding non-flying jobs in support career fields

UHT - Undergraduate Helicopter Training or a recent graduate

Outline of Subsequent Chapters

Chapter II provides a background to rated officer management and reviews modeling approaches used in the past to model personnel systems. Chapter III covers the modeling approach and output analysis used in this research. Chapter IV is the results of the analysis and Chapter V contains the conclusions drawn from that analysis.

II. Background and Literature Review

Introduction

This chapter describes how the Air Force manages rated officers and then gives brief descriptions of various methodologies that have been used to model personnel systems: in particular, military personnel systems. This review will help in the selection of the most appropriate modeling technique for the Pave Low system. The literature is reviewed in a topical order: rated officer management and personnel modeling approaches, which include both prescriptive and descriptive models.

Rated Officer Management

AFR 36-20 describes the gate system the Air Force uses to manage its rated officer force. Rated officers are required to complete six years of operational flying prior to being assigned to non-flying duties. Furthermore, "it is Air Force policy that as many members as possible perform at least 9 years of operational flying duty during the first 18 years of aviation service" (AFR 36-20:11).

Rated resource managers at AFMPC who manage the assignments of rated officers must balance these Air Force requirements with the need to provide officers the opportunity to broaden their careers in non-flying assignments such as staff duty, rated supplement, AFIT, and PME.

Additionally, the resource manager must consider what impact moving experienced personnel has on the flying organization. If a less-experienced replacement pilot must be absorbed into the unit, he must be allowed to fly to gain sufficient experience so he becomes an asset to the organization. Absorption capacity is "currently the most important factor" in determining the production rates of undergraduate flying training (Rated Management Document, 1987:6-1).

Davie (1988) said absorption could be a major problem for the Pave Low force as it expands and the pool of experienced helicopter pilots shrinks. Less-experienced pilots must have time to develop basic flying skills in addition to learning the Pave Low aircraft and mission. A linear programming model can be used to demonstrate how experience and stability requirements can severely restrict the number of inexperienced pilots (UHTs) the Pave Low force can absorb and still maintain its experience standard (Rated Management Document, 1987:6-3).

AFMPC recognizes that while a linear programming model can indicate an optimal mix of experienced and inexperienced pilots as inputs to the Pave Low force, that optimal mix will not necessarily reflect what is available for assignment (Rated Management Document, 1987:6-5). AFMPC needs a model of the force that will allow it to vary, among

5

other things, the mix of pilots to study the effects on force sustainment.

Personnel Modeling Approaches

Personnel models in the literature generally fall into one of two broad categories: prescriptive or descriptive. Prescriptive models prescribe an optimal solution for a given set of conditions. They generally involve some type of math programming such as linear programming (LP), goal programming, or network flow programming. Descriptive models are meant to imitate the systems and provide insight about that system. A common descriptive model is the simulation model (Olson, 1987:14,17).

Prescriptive Models.

Linear Programming. A linear programming model is a set of linear equations that bounds a feasible region. An objective function is used to determine a point within that region that represents an optimal solution. The simplex method, developed by Dantzig (Hillier and Lieberman, 1988:4), can be used to solve a linear programming problem.

Kleinman and Goudreau (1977) used linear programming to determine the optimal number of Navy officer accessions from nine commissioning sources. Within the constraint to fill required slots, the model minimizes life cycle costs.

Aronson and Thomson (1985) applied forward simplex to the multi-period linear goal programming problems of Charnes, Cooper, and Niehaus (Charnes et al., 1972). They used

6

Markov transition probabilities between personnel grades to determine promotions from one period to the next.

TOPOPS (Akam and Nordhauser, 1974) is a USAF officer procurement program that determines the best combination of officer recruits from the various commissioning sources. It can be used to minimize costs or to maximize the quality of 20 officer types over a five year period. Charpie (1987) used both linear programming and simulation to study the USAF B-52 navigator career field. The linear program determined the optimal state of the force, including optimal accession and training rates for a given scenario. As a basis for his LP model, Charpie used a cross-sectional network model such as the one in figure 1.
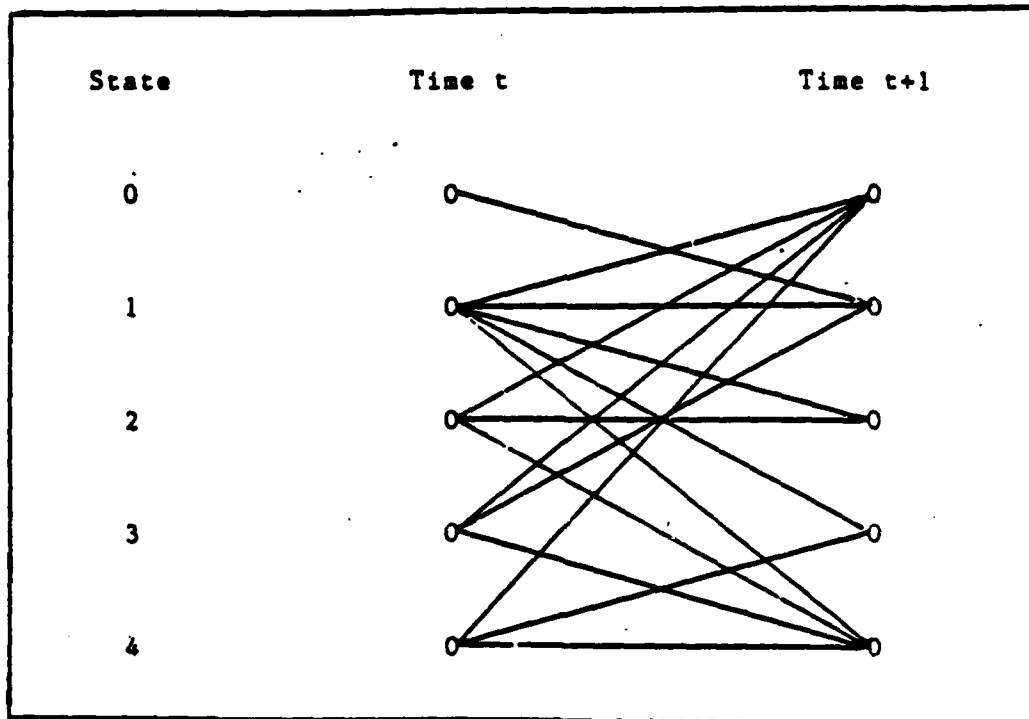
Figure 1. Cross-Sectional Network Flows
(Charpie, 1987)

This network represents positions or job types as nodes with
the connecting arcs representing possible movement from one
job (at time t) to another (at time t+1).

Charpie's LP model has five categories of constraints:
1) conservation of flow, 2) manning level requirements for
the various jobs, 3) minimum and maximum flows from one
position to another, 4) attrition, and 5) tour length. The
objective function seeks to minimize a variety of variables
including overall manning requirements, attrition,
accessions, and upgrade training.

Charpie used the LP model to establish an optimal steady
state condition for the navigator career field for a given
scenario. The model, however, did have drawbacks. Charpie
reported that the LP model could not incorporate as many
different aspects of the career field as the simulation
model could, it tended to ignore unrealistic personnel
allocations, and finally, the solution was merely a
"snapshot" in time and could not reflect, for example,
attrition over a period of time.

Goal Programming. Goal Programming is an adaptation
of linear programming that includes multiple goals in the
objective function. Charnes, Cooper, and Niehaus (1968)
developed several different personnel models for the US Navy
using goal programming embedded with Markov processes.

Siverd and Thomson (1979) used ratio goal programming to
assign personnel with various skill levels to jobs based on

a preferred mix of those skill levels. By doing so, they were able to maximize a measure of organizational effectiveness.

Network Flow Programming. Network models can be visualized as a set of nodes connected by arcs or paths. In a typical personnel network model, the nodes could represent jobs with individual workers flowing along the arcs, from node to node, as they change jobs. Thompson (1978) used a network transshipment model to approximate a linear programming model of a personnel system.

O'Conner (1982) developed an interactive computer program that used networks to model the Navy pilot force. The model was used to test the implications of various policy alternatives on Navy pilot requirements.

Liang and Thompson (1986) developed an assignment optimization model that uses a capacitated network to match Navy enlisted personnel to jobs according to Navy policy. People and jobs are both modeled as nodes with a connecting arc if an individual is eligible for that particular job.

Olson (1987) used a single-commodity network flow with side constraints to model the USAF rated officer force. The model balanced flying and non-flying assignments to ensure most rated officers met their flying gates.

Olson's network is four-dimensional in the following parameters: 1) time period under examination, 2) duty assignment, 3) aviation service date (ASD) year group, and

9

4) accumulated flying gate credit. Each node represents time (in years), the first parameter, and an individual's status, made up of the other three parameters. The arcs between the nodes represent assignments an officer could serve to get from one node/status to another node/status. Olson's network contains 975 nodes and 2374 allowable arcs.

The three dimensional network in figure 2 was taken directly from Olson's thesis. It illustrates how three of the four parameters interact. Arc 1 represents a one year assignment to duty type A, with a resulting increase in flying gate credit. Arc 2 represents a two year assignment to duty type B with no increase in flying gate credit.

The parameter not depicted in figure 2, ASD year group, increases directly with time. Thus the ASD year group for the individual at node B3/I is two years greater than it was when he was at node A1/I.

In addition to network flow constraints that prevent illogical assignments (such as AFIT followed by AFIT), Olson used side constraints to ensure that the model assigns sufficient personnel to each duty type without overmanning any of them. Side constraints were also used to ensure units are manned by sufficiently experienced personnel.

Olson used an optimization routine called NETSID to solve his formulation. NETSID is a simplex linear programming algorithm that can efficiently incorporate side constraints.
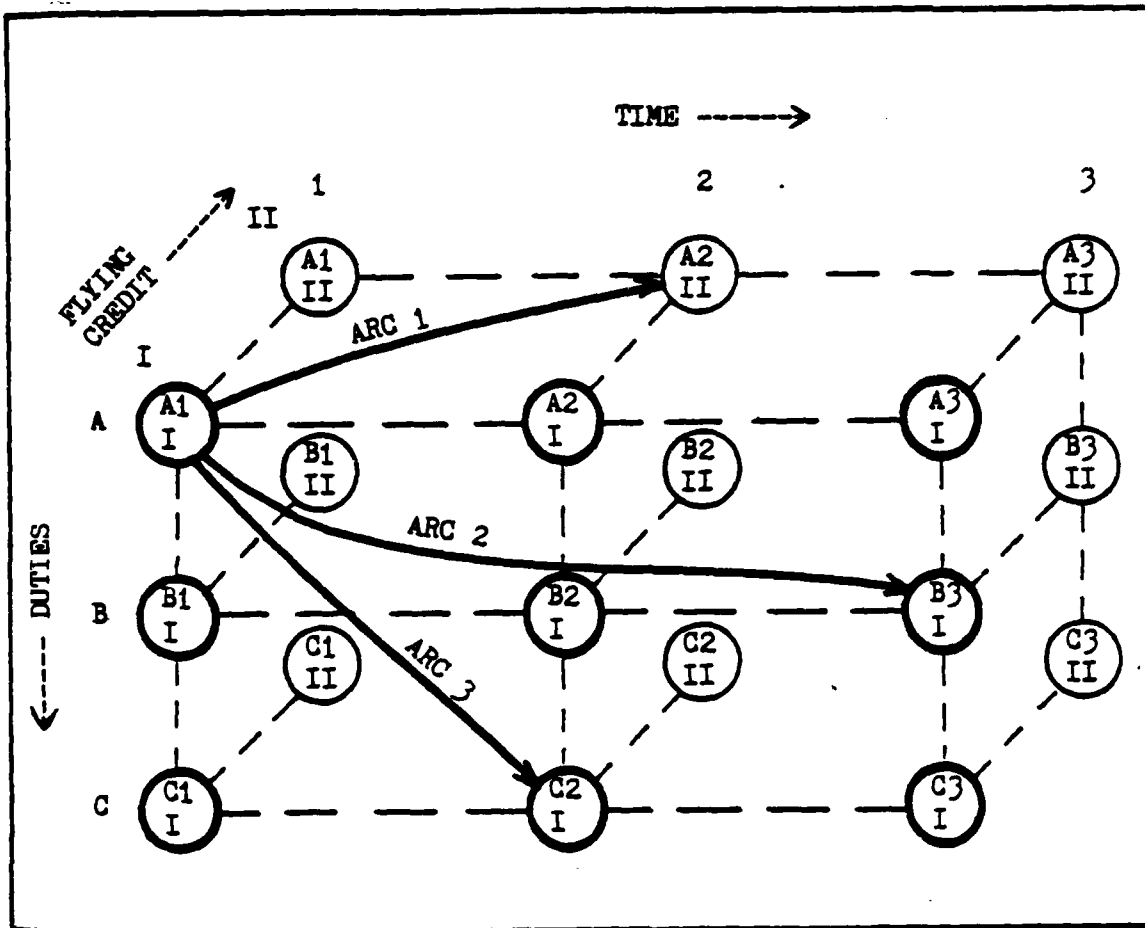
Figure 2.   Three-Dimensional Assignment Network
(Olson, 1987)

Olson defines a side constraint as any constraint that
applies to flow across multiple arcs.   The problem was
formulated as:

Minimize   cx

Subject to: Ax = r

$$Sx \begin{array}{c} \leq \\ = \\ \geq \end{array} b$$

$$0 \leq x \leq u$$

11

A is a matrix with a 1 if the arc flows out of the node, -1 if the arc flows into the node, and 0 otherwise. S is a matrix of side constraints with b as the right hand side. An example of a side constraint would be one that required a minimum of 60 percent of all flying duty positions to be occupied by pilots in ASD year group six or higher. To determine which arcs are affected, the program must consider all arcs terminating at flying duty nodes with an ASD year group greater than or equal to six. The total of these flows would have to be greater than or equal to 60 percent of the total flow into all flying duty nodes.

The r vector represents the requirements at each node and u is the vector of upper bounds for the arc flows. The x vector is the solution vector. The objective function minimizes total costs associated with failing to allow pilots to meet their flying gates by the time they get to a given ASD year group. The cost vector, c, represents the costs along arcs that represents such failures. For example, any node with an ASD value of 12 years or more and a gate credit value of fewer than six years represents a failure to meet the first (six year) gate. Any arc terminating at such a node would have a penalty or cost associated with it.

Descriptive Models.

Simulation Models. Computer simulations of personnel systems generally model at either the individual (entity) or

12

the group (aggregate) level. Entity models provide more detail, but can also require more input data and longer computer run times (Clark and Lawson, 1984:42). Leupp (1969) describes an entity simulation model the U.S. Navy uses to project the number of SEABEE personnel needed in the future. The model considers accessions, attrition, promotions, and assignment rotations.

Looper (1979) describes a large-scale entity simulation model called the Career Area Rotational Model (CAROM) that uses Monte Carlo techniques to model the career progression of airmen in the USAF. The model updates accessions, promotions, assignment rotations, and attrition on a monthly basis within a single career field for up to 30 years.

Percich (1987) simulated the career progression of USAF strategic airlift pilots as a basis to study moving costs. The model is a network and discrete-event simulation. He built the network representation of the career field using the SLAM II language (Pritsker, 1986). The entities that flow through the system are the individual pilots, modeled from the time they enter undergraduate pilot training (UPT) until they leave the Air Force. As each pilot moves from location to location with reassignments, the model collects data on moving costs associated with each pilot.

While the network structure of SLAM II is adequate to model the flow of pilots from one assignment to another, Percich wrote separate subroutines to initialize the

13

network, set tour lengths, model attrition, make assignments, and collect moving costs.

Using the results of experimentation with the simulation model, Percich developed two response surfaces. He first group screened a total of 12 predictor variables or factors, divided into five homogeneous groups. Using linear regression, he was able to identify three significant groups containing a total of eight factors. He then screened those remaining eight factors down to four significant factors. Based on those four factors, he built both linear and quadratic metamodels, polynomials that are significantly easier and quicker to use than a simulation model.

Charpie (1987) developed a model of the B-52 navigator career field in the U.S. Air Force and used it to examine changes in policies affecting the crew force. He used a network representation in which nodes represent the various jobs that a navigator can hold with navigators as the entities. The arcs represent allowable assignments for individuals at each stage of their careers.

Litko and Travis (1982) developed a dynamic simulation model to examine the potential consolidation of four USAF career fields into one. The model used a combination of the network, discrete-event, and continuous flow capabilities of SLAM. The flow of personnel to and from overseas assignments was modeled as a continuous process, while the actual consolidation of the career field was modeled as a

14

network activity. The discrete-event portion of the model was used to subtract or add personnel to the career field as technical school classes enter and graduate. The school takes personnel out of the system for the duration of the school.

Percich (1987) reports the Integrated Simulation Evaluation Model (Prototype) (ISEM-P) is a large-scale aggregate simulation that AFMPC can use to model the entire USAF personnel system. Starting with a mission plan, it establishes manpower requirements and, after considering attrition, determines the necessary accessions to build the required inventory.

Forrester (1980) developed systems dynamics to incorporate closed feedback loops into simulation models in an effort to more realistically represent real world interactions. Knight (1978) used systems dynamics in a highly simplified, aggregate model of USAF pilots. He used the model to examine policies controlling the size of undergraduate pilot training classes and instructor to student ratios.

Lawson (1982) used an aggregate simulation model of enlisted force structures within A.F. Communications Command (AFCC) to experiment with policies regarding the flow and distribution of personnel. His model also employed the system dynamics approach.

Clark and Lawson (1984) used the systems dynamics approach to model a segment of the USAF enlisted force that

is often assigned overseas. They started with an influence diagram that graphically showed both feedback structures and cause and effect relationships. Their simulation model required significantly less computer code and structure than it would have if they had used an entity model.

The models described in this chapter provide a basis on which to choose a methodology to model the Pave Low pilot force. The next chapter describes that methodology.

III. Methodology

Introduction

The purpose of this chapter is to examine the data available to build a model and then to discuss the modeling approach and the model itself. Included are discussions of the model assumptions, verification, validation, and experimental design.

Data Availability

Because the steady state Pave Low personnel system to be modeled is not yet a reality, data on the system is scarce. The relatively new career field has tended to hold pilots in the cockpit longer than in other weapon systems due to the complex nature of the mission and equipment. Furthermore, there is currently only one assignment location, whereas there will eventually be multiple locations. Because this research is intended to examine a steady state environment, data on average assignment/tour lengths, number of tours, and flying hours taken from the current system would be misleading at best.

As a result, most of the numbers used in this research have been gleaned from discussions with individuals at AFMPC, MAC, and 23rd AF. They are educated guesses at what the steady state system will look like. The exception is the retention data (see appendix A), which is actual historical data reflecting the entire helicopter force for the year 1987.

Model Assumptions

For the purpose of this investigation, it will be assumed that the system (career field) to be modeled is in steady state. That is, all the Pave Low helicopters are operational and in place, the units are fully manned, and some percentage of the pilots are temporarily in non-flying assignments. Since this steady-state system does not yet exist, however, the model will use reasonable estimates for parameters such as average time to upgrade from one crew position to another.

A sustained pilot force will be defined as 100 fully qualified pilots (not including those in staff positions), 60% of whom must be experienced Pave Low pilots. An experienced Pave Low pilot is one with at least 850 total flying hours, 300 of which must be in the Pave Low helicopter (AFR 51-2). Finally, these 100 pilots are assumed to be distributed across the different crew positions and ranks as they would in a real world flying squadron.

As previously mentioned, retention data used is from historical data. This data remains constant throughout the simulation, although in reality these figures would change somewhat from year to year. In fact, all system parameters such as input rates into the system (INP), the mix of UHTs (UHT) versus PQPs, and tour lengths (TRL) are constant throughout the simulation. In the real world, these

18

necessarily fluctuate with changing requirements and policies.

Promotions to higher grades and upgrades to higher crew positions are not modeled. It is assumed these occur at normal rates and times. In reality, if it were perceived that promotions and upgrades lagged behind those in other career fields, retention rates would probably decline.

Modeling Approach Selection

The models discussed so far can be categorized as dynamic or static, stochastic or deterministic, aggregate or entity, and prescriptive (optimization) or descriptive (non-optimization). The relative advantages and disadvantages of these various approaches depend on the system to be modeled.

Personnel systems are by nature dynamic, that is, changing over time. Static models generally ignore the passage of time, instead taking a "snapshot" in time of that system. Litko (1982:33) says this method can be misleading when modeling a changing process such as a personnel career field. For this reason, a dynamic model seems to be appropriate for this research.

Similarly, real-world personnel systems have a degree of unpredictability about them. To treat a career field as deterministic suggests the ability to predict or predetermine factors such as tour lengths or individual career decisions. A stochastic model, on the other hand, uses random numbers to model the variability in such factors

and will therefore be used.

Litko (1982:36) says the disadvantages of an entity model for large personnel systems are the need for an extensive data base and longer computer run times. The disadvantage of the aggregate approach is the potential loss of necessary detail and validity.

The Pave Low pilot data base is currently very small since it is a relatively new weapon system. Even when it reaches its projected peak, it will consist of just over 100 actively flying pilots with about that many in non-flying positions. With so few entities to model, the need for detail seems to outweigh the difficulty of dealing with a large data base. Furthermore, initial runs of a simple prototype entity simulation model suggest very short computer run times: only a few seconds actual CPU time.

The question of whether to use an optimization or non-optimization model should be tied to the type of questions to be answered with the model. The primary objective of this research is to provide AFMPC with a tool to study the impact (on the Pave Low pilot force) of policy decisions, particularly decisions concerning the allowable mix of UHTs versus PQPs as inputs to the Pave Low system. This research is intended to provide "an array of acceptable policies ... from which the planner can choose the one with the best tradeoff." (Jaquette et al., 1977:6). Furthermore, it should allow decision makers to ask "what if" questions and

20

evaluate tentative results without actually implementing any policies. A secondary objective is to determine, for a given set of circumstances, an optimal policy.

To meet the first objective, the modeling approach of choice will be a dynamic, stochastic, entity simulation (non-optimization) model. Response surface methodology will be applied to the simulation output to develop response equations that describe the responses in terms of policy variables. These equations will, in turn, be used as goals in a goal programming (optimization) model to determine an optimal policy, one that meets the manning and experience goals as closely as possible.

Model Overview

The Pave Low simulation model was fashioned after Percich's Strategic Airlift PCS cost simulation model (Percich, 1987). Percich modeled a rated career field, the strategic airlift pilots, in order to study permanent change of station (PCS) costs. His model is an entity simulation model written in SLAM II, a language which is also available for this research. Like that model, the Pave Low model breaks the pilot's career into three periods: one to six, seven to eleven, and twelve to seventeen years. The period from 18 years to retirement is modeled, but not considered for flying assignments.

The first period, from one to six years, consists of flight school for UHTs, Pave Low school (CCTS), and the

21

first flying assignment(s). Non-flying assignments are not allowed during this period in keeping with gate requirements. Subsequent periods include both flying and non-flying assignments. Figure 3 is a macro flow chart of the Pave Low Simulation Model.

Intended Use of the Model

The Pave Low simulation model is intended to provide decision makers a range of options to sustain the Pave Low force at required manning and experience levels. It allows decision makers to ask "what if" questions; that is, to change key parameters and see the potential impact a policy decision might have on the actual system.

Pave Low Simulation Model

The model itself is written in SLAM II. SLAM II is a FORTRAN based modeling language with the capability to incorporate both discrete-event and continuous modeling into a network model (Pritsker, 1984).

SLAM II Network Code. Entity attributes, values associated with particular entities, and global variables, which are not associated with any particular entity, are defined in table 1. A network diagram and the network computer code appear in appendices B and C. The first create node creates an entity whose sole purpose is to call subroutine CLEAR at 200 time units (months). Subroutine CLEAR clears all statistical arrays of transition period

22
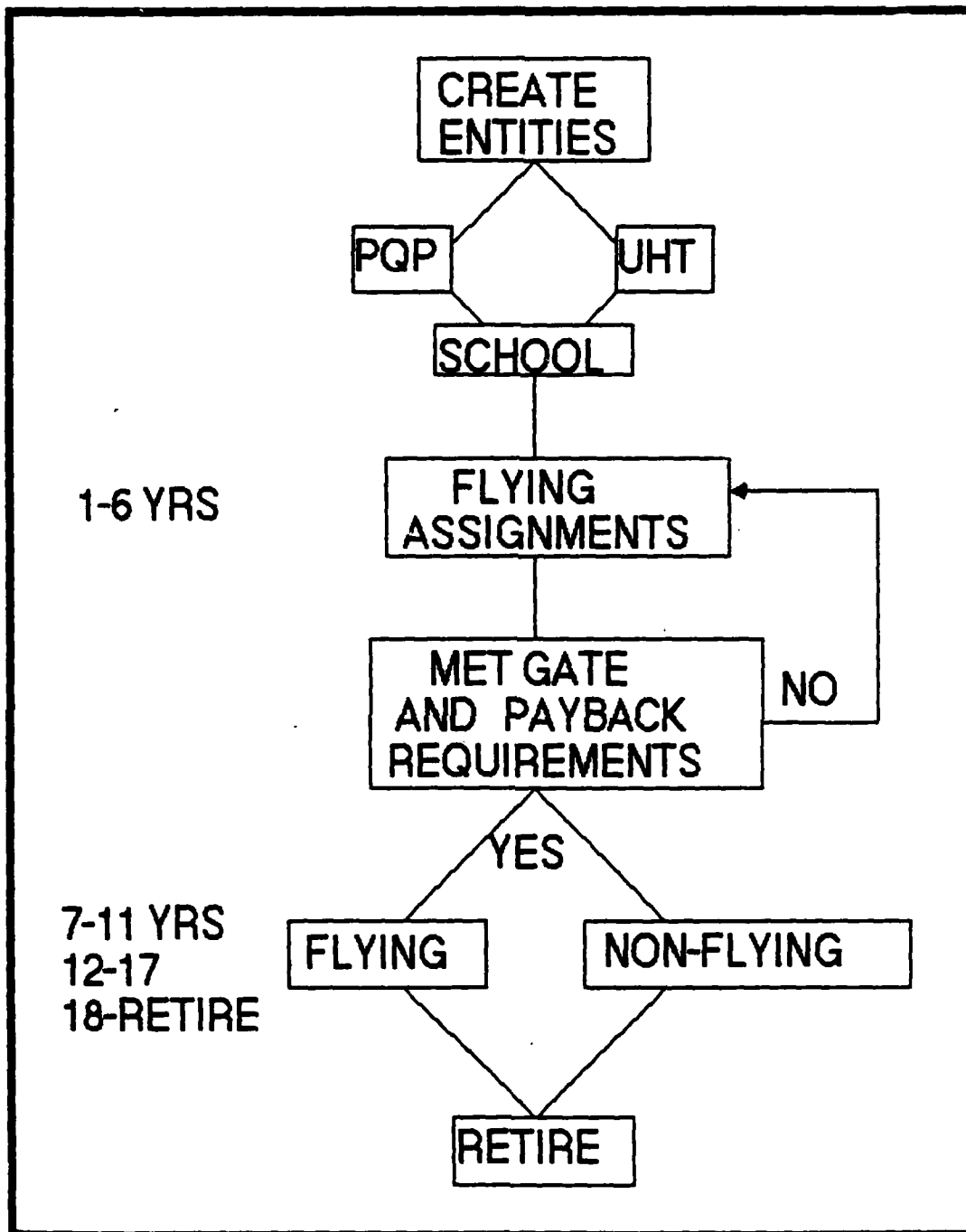
Figure 3. Pave Low Model Flow Chart

data in order to eliminate bias created by the warm-up period prior to steady state.

The second create node creates an entity every XX(6) months that represents a CCTS class of two student pilots.

Table 1   SLAM II Attributes and Variables

Attribute

1	tour length
2	hours per tour
3	pilot type (UHT or PQP)
4	time in service
5	Pave Low flying hours
6	hours until experienced
7	separation indicator
8	CCTS class size

Global Variable

1	number of experienced pilots
2	number of actively flying pilots = TOT
3	hours required
4	XX(1)/XX(2) = EXP
5	excess hours
6	time between class creations
7	percent UHT
8	low side tour length distribution
9	mode of tour length distribution
10	high side tour length distribution
11	hours payback (PAY)
12	total number of blocked cockpit seats

XX(7) percent of those pilots are labeled UHTs and have a time-in-service of 12 months (for flight school and a PCS). The rest of the pilots are labeled PQPs and have a time in service drawn from a triangular distribution with low, mode, and high values of 42, 48, and 54 months respectively. In the absense of a known distribution, the triagular

24

distribution was used to provide a range of possible values with the mode being the most likely value. This represents approximately a year for flight school and a three year tour in another type of helicopter. All students are sent to CCTS for seven months (accumulating 80 Pave Low hours), at which time they are counted as part of the actively flying line force.

Next, the pilots are assigned a tour length drawn from a triangular distribution, again, since it is not a known distribution. The event node calls subroutine FLIER, which determines retention/separation status and updates applicable attributes, such as Pave Low flying hours. If a UHT needs more flying time in order to reach 850 hours, he is looped back for a second assignment.

The next section of the network determines, to the month, when each pilot becomes experienced and immediately updates the ratio of experienced to total active pilots. Pilots who separate before becoming experienced are collected at a different node from those who separate after becoming experienced.

Pilots who have not finished paying back for their Pave Low training are looped back for another flying assignment. The rest move on to the 7 to 11, or the 12 to 17 year group, as appropriate. From Queue3, XX(12)/2 pilots are blocked for flying assignments beginning sometime during the 7 to 11 year period. The same number, XX(12)/2 are blocked in the

12 to 18 year group. XX(12) is the total number of blocked cockpits, but these are divided between two career stages. After these slots are filled, the remainder of the pilots fill non-flying assignments. These non-flying pilots are subtracted from the force and the experience level is recalculated.

The 12 to 17 year group part of the network parallels the previous section. The 18 year to retirement section was only used for non-flying assignments for this research, but could be used to block cockpits for more senior pilots. The final section of the model is data collection nodes.

FORTRAN Subroutines. FORTRAN subroutines are located in appendix D. Subroutine INTLC is used to read in the parameter values from a coded design matrix. It then decodes the parameters into a form meaningful to the SLAM II network. The subroutine also holds the retention data table. Subroutine INTLC could be used to initialize or load the network to shorten the transition period to steady state.

Subroutine FLIER rounds the time in service and pending tour length to whole years in order to apply the retention data. It then makes a draw from a uniform (0,1) distribution and compares that number to the applicable retention figures. If the random draw is greater than the retention figure for any year of the pending assignment, the tour length is shortened and attributes are updated

accordingly. The entity is given a separation indicator that will cause it to leave the network. If the entity does not separate, flying hours and time-in-service are updated according to the originally assigned tour length. Subroutine NONFLY is identical to subroutine FLIER, except flying hours are not updated.

Subroutine OTPUT writes the six predictor variables and the two response variable values to a file. This file can then be read directly by a statistical package, such as SAS.

Verification

The network model and FORTRAN subroutines were verified as the model was being built. The SLAM II MONTR/TRACE option allows entities and attributes to be monitored all the way through each part of the network to ensure the model was operating as desired. Likewise, all input parameters were written to files to ensure that the output made sense for that input.

Validation

Because the real-world system being modeled has not yet reached anything close to steady state, it is difficult to compare the model output to actual data. And since the Pave Low system is so small and unique, it is not easy to make comparisons to another weapon system or to the helicopter system as a whole. However, as the Pave Low system approaches steady state, data will become available to help modify and validate the model.

Experimentation

Experimental Design. Examples of experimental designs
are located in appendix E. The first portion of the
analysis will consider a number of factors/variables that
are suspected as being significant and screen out those
which are insignificant. With a large pool of possibly
significant factors, the first step is to group homogeneous
factors and use regression analysis to screen out entire
groups of insignificant factors. The remaining factors are
ungrouped and individually screened for significance. The
factors remaining after this two-stage screening process are
then used to build the first-order metamodel. A metamodel
is a model of a model. In this research, it is a polynomial
equation that "captures" what the simulation model is doing.
A lack of fit test reveals whether or not the response
surface is a plane or is curved, the latter requiring a
second-order metamodel. This process of building a response
surface is pictured in figure 4.

In this particular research, group screening was not
needed because only six factors were examined. The factor
screening stage of the analysis screened the six predictor
variables or factors to determine which have significant
impacts on the two response variables.
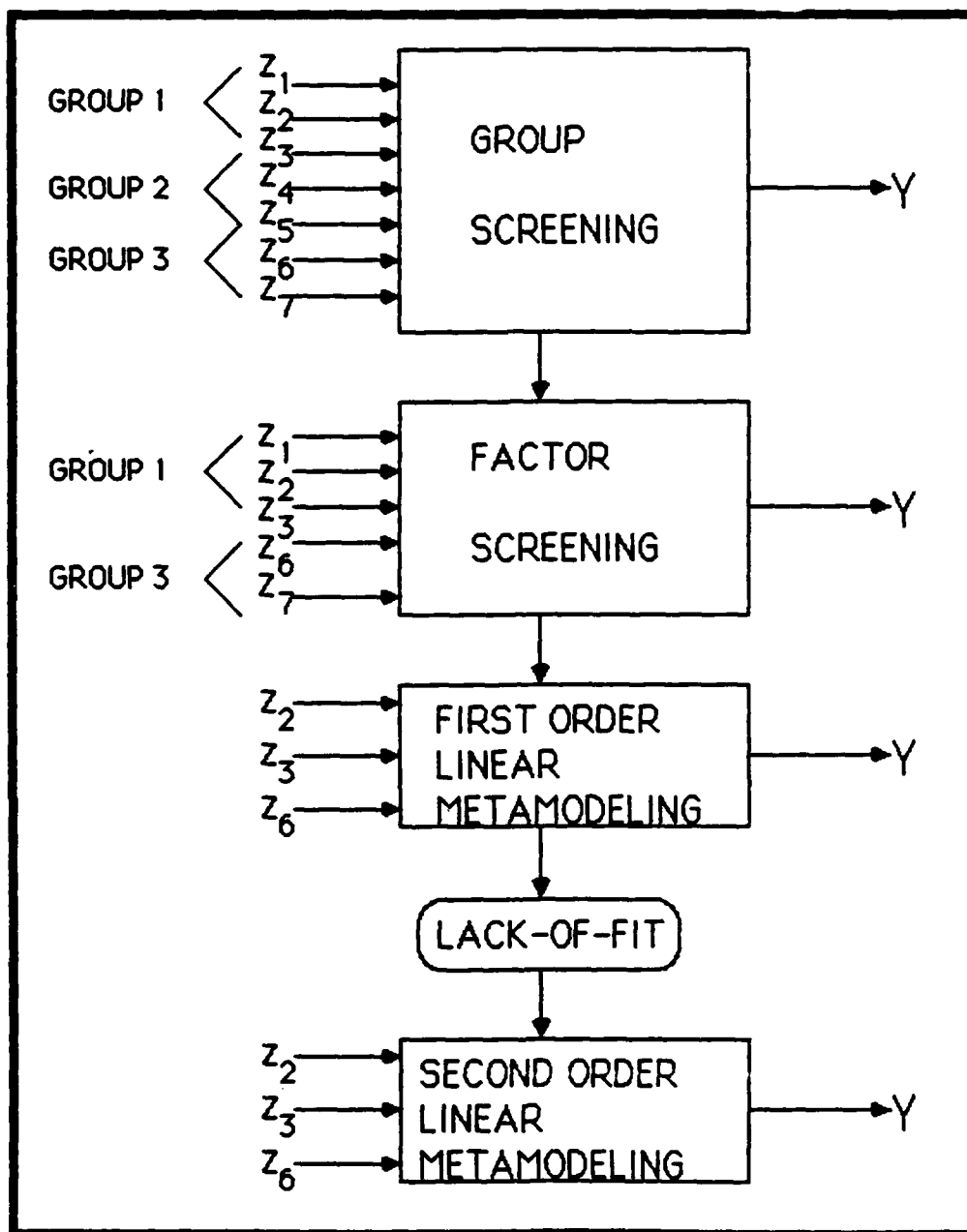
Figure 4. Metamodel Building Process
(Bauer, 1988)

29

The six predictor variables are:

1) INP (Input) - the average number of pilots who enter the Pave Low system each year, either directly from flight school (Undergraduate Helicopter Training) or by cross-training from another type of helicopter.

2) UHT - the percentage of "INP" who come directly from flight school, with no previous operational flying experience.

3) TRL (tour length) - the length, in months, of the average flying tour/assignment.

4) BLK (block) - the number of blocked cockpits. Blocked cockpits are flying positions reserved for previously qualified Pave Low pilots who are currently serving in the rated supplement, but who eventually return to the cockpit. The more blocked cockpits, the fewer new inputs can be brought into the system.

5) PAY (Payback) - the amount of time (in flying hours) a trained Pave Low pilot is expected to remain in the cockpit. The greater the payback requirement, the more experienced the pilot force will be.

6) HRS (hours) - the average number of flying hours each pilot flies each month. The more hours, the more experienced the force.

The two response variables are:

1) TOT - Total operational pilot force. This includes only line pilots in full-time, operational flying (excludes

staff, school instructors, etc.).

2) EXP - The percentage of "TOT" who are "experienced", meaning they have 850 total flying hours, 300 of which are in the Pave Low helicopter. The desired operating conditions for the model are defined in terms of TOT and EXP. The number of authorized line pilots is approximately 100, so TOT values that vary significantly from 100 suggest an over or under-manned organization. Likewise, the Pave Low experience level (EXP) should remain at or above 60% (AFR 51-2). The two response variables must be examined together. In other words, it is not acceptable to have an EXP of 70% if TOT is very low or very high.

A full factorial, two level experimental design (2^6) with replications was used. The Statistical Analysis System (SAS) will be used to create an Analysis of Variance (ANOVA) table for each response variable. The F statistic will then be used to determine model adequacy and significance of factor effects. Furthermore, assumptions regarding constant variance and normality of residuals will be examined using residual plots (Montgomery, 1984:85-93, 223-224).

From the regression analysis, a first-order metamodel will be developed. That model will be checked for lack of fit to determine if a second-order model is required. If so, an appropriate three-level design (depending on the number of significant linear factors) will be used to construct a second-order metamodel.

Goal Programming Model. Once reasonable response surface equations for the two response variables have been developed, those two equations will be set equal to constant values that reflect the goals of 100 pilots with a 60% experience level. These goals, with associated deviation variables, will become constraints in a mathematical programming problem. The objective function will seek to minimize deviations from the goals. Upper and lower bounds will be placed on the predictor variables to restrict them to the experimental region. The solution to the goal programming problem should provide optimal settings for the predictor variables in order to achieve, as closely as possible, the stated goals.

This chapter described the Pave Low model and the experimental design for the output analysis. The next chapter discusses the results of that output analysis.

IV. Analysis

Introduction

The purpose of this chapter is to describe the operation
of the SLAM model and the analysis of the model output using
response surface methodology and goal programming. The
response surface methodology is used to build response
equations that are then used as goals in the goal
programming formulation. The goal programming model, in
turn, determines optimal values for the decision variables.

SLAM II Model Operation

To estimate the length of the transient period, several
model runs were conducted for time periods of 100 years.
The time average of the experience level was then plotted
(See appendix G). The plot indicates the model has a warm-
up period of approximately 150 months before reaching a
steady state condition. In subsequent runs, all
statistical arrays were cleared after 200 months. The model
was then allowed to run for another 700 months or about 60
years.

Output Analysis

Factor Screening. The model was run using ten
replications of the six-factor, two-level full factorial
design with the six predictor variables shown in table 2.
These variables, along with the two response variables were
analyzed using SAS procedures PROC REG and PROC STEPWISE.

Table 2. Factors and Settings

FACTOR	LOW	HIGH
INT	12	24
UHT	0	.5
TRL	36	60
PAY	500	750
BLK	0	30
HRS	10	15

The residual plot from the second response variable, TOT, indicated a slightly increasing variance. A natural log transformation of the response corrected the problem (All residual plots and normality plots are in appendix F). The resulting ANOVA tables are in tables 3 and 4.

Table 3. ANOVA for EXP factor screening

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	93673.59	15612.26	866.10	0.0001
INP	1	758.21	758.21	42.06	0.0001
UHT	1	65642.40	65642.40	3641.54	0.0001
TRL	1	3691.20	3691.20	204.77	0.0001
BLK	1	13987.60	13987.60	775.97	0.0001
PAY	1	6347.88	6347.88	352.15	0.0001
HRS	1	3246.30	3246.30	180.09	0.0001
ERROR	633	11410.45	18.026		
TOTAL	639	105084.04		ADJ R^2 = .89	

Table 4. ANOVA for TOT factor screening

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	98.38	16.40	1006.49	0.0001
INP	1	60.89	60.89	3737.30	0.0001
UHT	1	6.64	6.64	407.53	0.0001
TRL	1	2.68	2.68	164.32	0.0001
BLK	1	11.34	11.34	695.92	0.0001
PAY	1	5.92	5.92	363.17	0.0001
HRS	1	10.93	10.93	670.72	0.0001
ERROR	633	10.31	.016		
TOTAL	639	108.70		ADJ R^2 = .90	

The p values of 0.0001 for the six predictor variables indicate that all six are significant. It was noted, however, that UHT was, by far, the most significant factor to EXP, and INP was the most significant to TOT (based on significantly larger F values). To further simplify the linear metamodel, then, the remaining four factors were screened out.

First Order Metamodel. Ten replications of a three-level, two-factor full factorial experimental design were run. A two-level, two-factor design was used in a trial run and indicated that a second order model was needed. The four screened factors were set to constant, nominal values so they would not influence the results. Factor settings are shown in table 5.

The two-factor linear model residual plots were convex curves, indicating quadratic tendencies, which were confirmed by using SAS procedure PROC RSREG. This procedure breaks the regression or model sum of squares into linear,

Table 5. Factor Settings for First-Order Metamodel

FACTOR	LOW	MID	HIGH
INP	12	16	24
UHT	0	.25	.50
TRL		48	
PAY		680	
BLK		15	
HRS		12.5	

quadratic, and cross-product components. Tables 6 and 7
show both significant quadratic and cross-product
components. If a two-level design had been used instead of
a three-level design, PROC RSREG's lack of fit test would
have indicated a lack-of-fit for a linear model. That was
the case in the trial run.

Table 6. First-order lack-of-fit for EXP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
LINEAR	2	13256.83	6628.41	18725.26	0.0001
QUADR	2	25.69	12.84	36.29	0.0001
CROSS	1	7.26	7.26	20.51	0.0001
TOTAL	5	13289.78	2657.96	7508.72	0.0001
RESIDUAL					
L.O.F.	3	2.65	0.88	2.57	0.0552
PURE E.	171	58.94	0.34		
TOTAL	174	61.59	0.35	ADJ R^2 = .99	

Table 7. First-order lack-of-fit for TOT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
LINEAR	2	165973.55	82986.78	62480.93	0.0001
QUADR	2	5739.51	2869.76	2160.64	0.0001
CROSS	1	753.38	753.38	567.22	0.0001
TOTAL	5	172466.44	34493.29	25970.07	0.0001
RESIDUAL					
L.O.F.	3	18.70	6.23	5.02	0.0025
PURE E.	171	212.41	1.41		
TOTAL	174	231.11	1.33	ADJ R^2 = .99	

Second Order Metamodel. The residual plots for the second- order model based on the two factors, INP and UHT, indicate a non-constant, decreasing variance for response variable EXP and a non-constant, wave pattern for TOT. These could indicate the need for a transformation. Several transformations were tried, including natural log, arcsin, and square root functions of the response variable. Based on residual plots, the best transformations were ln(84-EXP) and ln(TOT). ANOVA tables are in tables 8 and 9.

Table 8. ANOVA for second-order metamodel (EXP)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	71.48	14.30	8770.87	0.0001
INP	1	1.27	1.27	784.38	0.0001
UHT	1	66.33	66.33	40913.57	0.0001
UHT*UHT	1	3.63	3.63	2241.22	0.0001
INP*UHT	1	0.25	0.25	152.70	0.0001
ERROR	175	0.28	0.0016		
TOTAL	179	71.77		ADJ R^2 = .99	

Table 9. ANOVA for second-order metamodel (TOT)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	11.63	2.33	25580.85	0.0001
INP	1	10.87	10.87	120045.03	0.0001
UHT	1	0.63	0.63	6968.06	0.0001
INP*INP	1	0.13	0.13	1450.75	0.0001
INP*UHT	1	0.01	0.01	13.49	0.0003
ERROR	175	0.02	0.00009		
TOTAL	179	11.65		ADJ R^2 = .99	

After decoding, the second order metamodel for response EXP was:

$$\ln(84-EXP) = 1.3312 + 0.0265*INP + 6.0524*UHT$$
$$(.007) \quad\quad (.004) \quad\quad\quad\quad (.004)$$

$$- 4.8224*UHT^2 - 0.0371*INP*UHT$$
$$(.006) \quad\quad\quad\quad (.005)$$

The second-order metamodel for TOT was:

$$\ln(TOT) = 4.2696 - 0.0078*INP + 0.2432*UHT$$
$$(.002) \quad (.001) \quad\quad\quad (.001)$$

$$+ 0.0016*INP^2 + 0.0026*INP*UHT$$
$$(.002) \quad\quad\quad\quad (.001)$$

Figure 4 shows both responses plotted in the INP/UHT plane. Since both response surfaces were second order, they are both paraboloids. The figure is a plot of the projection of the paraboloid contours in the INP/UHT plane. The contours are nearly straight lines because the region of interest is so far from the parabolas' vertices. This figure will vary with the values used for the other four decision variables (TRL, PAY, BLK, AND HRS). This

particular figure is based on the values listed previously in table 5.
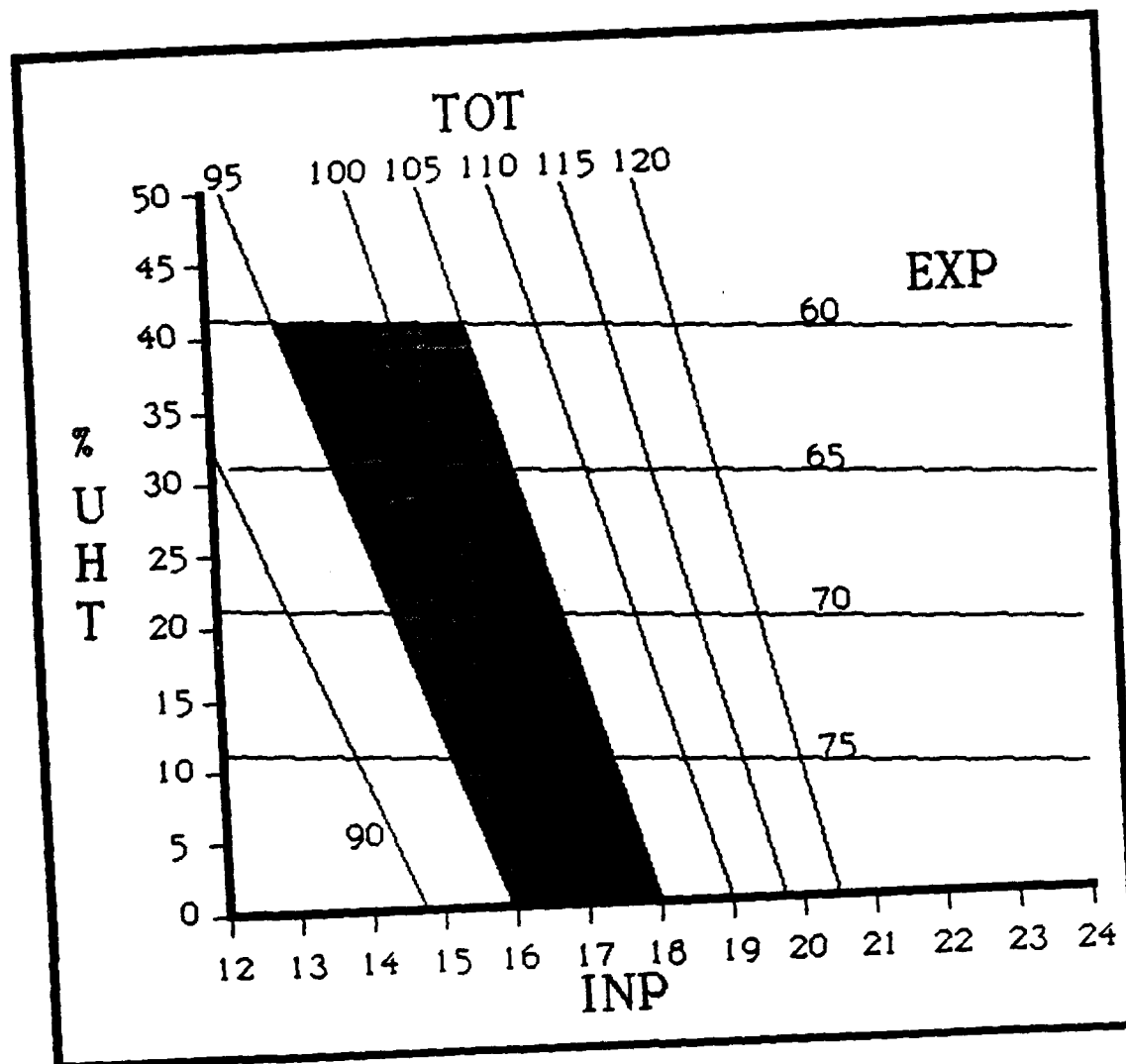
Figure 5. Second-Order Metamodel Contours

39

Goal Programming. Goal programming is a form of mathematical programming that allows more than one objective to be achieved in the same problem. So rather than minimizing or maximizing one objective, goal programming minimizes deviations from one or more established goals. Goals can be prioritized and deviations can be weighted depending on the judgment of a decision maker or expert (Hillier and Lieberman, 1986: 242-246).

The two goals in this research are: 1) to maintain the force (TOT) at close to 100 pilots and 2) to maintain the force experience level (EXP) at a minimum of 60%. A linear goal programming problem was formulated as follows, using the six-factor linear metamodels in the goal equations:

Minimize: $d_1^- + d_2^- + d_2^+$

Subject to: 1) $36.79 - 0.81\text{INP} - 40.52\text{UHT} + 0.2\text{TRL} +$
$0.03\text{PAY} + .31\text{BLK} + 0.90\text{HRS} + d_1^- - d_1^+ = 60$

2) $-19.78 + 6.05\text{INP} + 45.36\text{UHT} + 0.64\text{TRL} +$
$0.09\text{PAY} + 0.92\text{BLK} - 6.20\text{HRS} + d_2^- - d_2^+ = 100$

3) $12 < \text{INP} < 24$

4) $0 < \text{UHT} < .5$

5) $36 < \text{TRL} < 60$

6) $500 < \text{PAY} < 750$

7) $0 < \text{BLK} < 30$

8) $10 < \text{HRS} < 15$

The "d" variables are the deviation variables for the two goals. Since the experience level can be allowed to go

above, but not below 60%, d_1^+ was left out of the objective function. The remaining three deviation variables are minimized. All the predictor variables have lower and upper bounds, to keep the solution set within the experimental region.

The goal programming model was run on LINDO (Schrage, 1986), a linear programming package. The results, after 13 iterations, were:

```
INP =  17.92
UHT =   0.12
TRL =  36.0
PAY = 500.0
BLK =   0.0
HRS =  10.0
```

        Objective function value = 0.0
        All deviation variables = 0.0

Thus, the goals were able to be met exactly by setting all but the first two predictor variables to their lower bound. These optimal values were run in the Pave Low simulation model and produced an EXP value of approximately 61 percent and a TOT value of 109. While not exactly on target, they are an indication the goal programming model accurately reflects the simulation model output.

In contrast, the second-order metamodels were used as goals in a non-linear goal programming problem. The optimal solution was to set INP to 14.2 and UHT to 42 percent. When this solution was run in the simulation model, it met the experience goal, but exceeded the manning (TOT) goal by about 22. The difference beteen the two metamodels (linear

vs quadratic) is the linear includes the four less significant decision variables. These four variables help provide a better reflection of the simulation in the metamodel equations.

The difficulty with any "optimal" solution is that it may not be practical. Although all the predictor variables are decision variables and can be controlled, some are more easily varied than others. Since INP and UHT are probably the easiest to change, the other predictor variables can be set to values that seem to most closely reflect reality and let the model solve for INP and UHT.

This chapter discussed the analysis of the simulation output. In light of this analysis, the next chapter will make policy recommendations as well as recommendations for further research.

V. Summary and Recommendations

Introduction

This chapter summarizes the research and its implications, and then provides recommendations for policy decisions and further research.

Summary of Research

The objective of this research was to model the Pave Low pilot career field and to examine how best to sustain an experienced pilot force. This was accomplished by developing a simulation model that permitted experimentation with key policy/decision variables. Response surface methodology was then used to screen out less important variables and to develop response equations which captured the simulation outcomes in simple polynomials. These polynomials were used to define goals within a goal programming model. That model produced optimal values for the policy variables in order to achieve the desired manning and experience levels for the Pave Low pilot force.

Implications

The value of this research is in developing a methodology both to describe the Pave Low pilot career field and to determine optimal policy decisions. As more complete data on the pilot force becomes available, the models used in this research can be easily modified to more accurately reflect reality.

Policy Recommendations

This research suggests two policy recommendations once the Pave Low pilot force is fully manned. First, only about ten percent of the pilots entering the Pave Low should be right out of Undergraduate Helicopter Training (UHT) to avoid causing the experience level to drop below 60 percent. Second, the input rate into the system will probably have to be reduced slightly from the current twenty pilots per year to prevent over-manning. The exact amount of reduction will depend on future retention rates.

Recommendation for Future Research

Future research should focus on the implications of overseas basing, such as how short overseas tours and the ratio of overseas to stateside assignments affects manning and experience levels.

Appendix A: Retention Rates

Year of Service	Retention Rate
1	1.000
2	.986
3	1.000
4	.958
5	.974
6	.971
7	.909
8	.963
9	.955
10	.977
11	.875
12	.886
13	.892
14	1.000
15	1.000
16	.983
17	1.000
18	.955
19	.906
20	.745
21	.521
22	.667
23	1.000
24	.778
25	.500

NNACT(46).LT.15

A(1)=TRIAG

1

A(1)

A(1)=TRIAG
ACTV=ACTV−1
EXPD=EXPD−1
PERC=EXPD/ACTV

2

A(1)

ACTV=ACTV+1
EXPD=EXPD+1
PERC=EXPD/ACTV

Q3 G5

A(4).LT.132

NNACT(58).LT.15

A(1)=TRIAG

1

A(1)

A(1)=TRIAG
ACTV=ACTV−1
EXPD=EXPD−1
PERC=EXPD/ACTV

2

A(1)

ACTV=ACTV+1
EXPD=EXPD+1
PERC=EXPD/ACTV

A(7).EQ.1

G6 Q4 Q7

DEPT

A(4).LT.204

NNACT(70).LT.0

A(1)=TRIAG

1

A(1)

A(1)=TRIAG
ACTV=ACTV−1
EXPD=EXPD−1
PERC=EXPD/ACTV

2

A(1)

ACTV=ACTV+1
EXPD=EXPD+1
PERC=EXPD/ACTV

A(7).EQ.1
DEPT

G8 Q5 Q9

A(4).LT.240

ACTV=ACTV−1
EXPD=EXPD−1
PERC=EXPD/ACTV

ALL RETIREES

G10

A(7).EQ.1.
AND
A(4).LT.240

ACTV=ACTV−1
EXPD=EXPD−1
PERC=EXPD/ACTV

ALL SEPARATED

DEPT

47

Appendix B: SLAM II Network Diagram
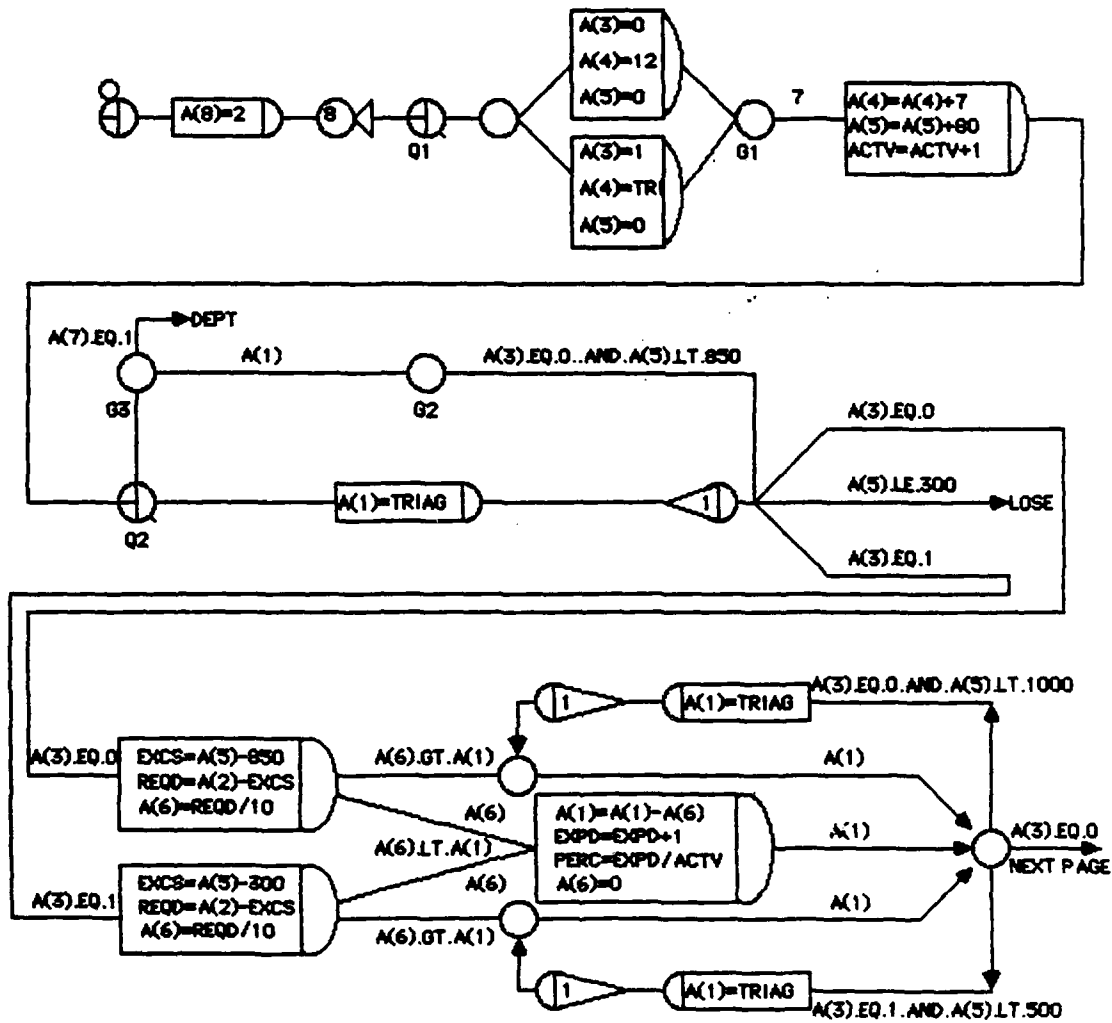
Appendix C: SLAM II Code

```
GEN,MCKOY,PAVE1,6/15/1988,32,N,N,,N,N,72;
LIMITS,5,8,750;
TIMST,XX(4),PERCENT EXPERIENCED;,20/0./.05;
TIMST,XX(1),NO OF EXP PILOTS;
TIMST,XX(2),NO OF ACTIVE PILOTS;
SEEDS,1145661099(1);
;RECORD,TNOW,TIME,,P,5.0;
;VAR,XX(4),.,,PERCENT EXPERIEN,0.0,1.0;
EQUIVALENCE/XX(1),EXPD/
            XX(2),ACTV/
            XX(3),REQD/
            XX(4),PERC/
            XX(5),EXCS;
NETWORK;
;CLEAR STATISTICAL ARRAYS AT TNOW=200
        CREATE,,200;
CLEAR   EVENT,3;
        TERM;


;CREATE A CLASS OF 2 STUDENTS W/ T.B.C. OF XX(6)
        CREATE,XX(6);
        ASSIGN,ATRIB(8)=2,1;
        UNBATCH,8,1;


QUE1  QUEUE(1);
        ACT(20);


;LABEL STUDENTS AS UHTS OR PQPS
        GOON,1;
          ACT/1,,,XX(7),UHT;UHTS
          ACT/2,,1-XX(7),PQP;PQPS


;UHT IS ASSIGNED TIME IN SERVICE OF 12 MONTHS
UHT    ASSIGN,ATRIB(3)=0.,
              ATRIB(4)=12.,
              ATRIB(5)=0.,
              ATRIB(7)=0.,1;
          ACT,,,G1;


;PQP IS ASSIGNED T.I.S. IAW TRIANGULAR DISTRIBUTION
PQP    ASSIGN,ATRIB(3)=1.,
              ATRIB(4)=TRIAG(42.,48.,54.,1),
              ATRIB(5)=0.,
              ATRIB(7)=0.,1;
;CCTS TAKES 7 MONTHS,80 FLYING HOURS
G1     GOON,1;
          ACT/3,7.;CCTS
```

```
          ASSIGN,ATRIB(4)=ATRIB(4)+7.,
                 ATRIB(5)=ATRIB(5)+80.,
                 ACTV=ACTV+1.,
                 PERC=EXPD/ACTV,1;
;STUDENT IS NOW AN ACTIVE, THOUGH INEXPERIENCED PILOT

;PILOT GETS FIRST OPERATIONAL ASSIGNMENT
;TOUR LENGTH IAW TRIANGULAR DISTRIBUTION
QUE2  QUEUE(2);
          ACT(100);
      ASSIGN,ATRIB(1)=TRIAG(XX(8),XX(9),XX(10),1),1;

;SEE FORTRAN CODE
E1      EVENT,1,1;

;UHT GETS A 2ND TOUR TO GET 850 HRS
          ACT/4,,ATRIB(3).EQ.0.0.AND.ATRIB(5).LT.850.,G2;GET
EXPER
;UHTS W/ 850 HRS
          ACT/6,,ATRIB(3).EQ.0.,UHTX;EXP-UHT
;PQPS WHO ATTRIT FROM SYSTEM W/O GETTING 300 HRS
          ACT/8,,ATRIB(5).LE.300.,LOSE;FIRST YR LOSS/PQP
;PQPS W/ 300 HRS
          ACT/10,,ATRIB(3).EQ.1.,PQPX;EXP-PQP

G2      GOON,1;
          ACT/12,ATRIB(1),,G3;

G3      GOON,1;
;UHTS WHO ATTRIT DURING FIRST TOUR
          ACT/14,,ATRIB(7).EQ.1.0,LOSE;SEPAR1
          ACT/16,,,QUE2;

;COMPUTES #OF MONTHS INTO TOUR THAT PILOT
;REACHES EXPERIENCED STATUS (850 HRS)
UHTX  ASSIGN,EXCS=ATRIB(5)-850.,
                 REQD=ATRIB(2)-EXCS,
                 ATRIB(6)=REQD/15.,1;

;UHTS WHO ATTRIT DURING 2ND TOUR W/O REACHING 850 HRS
          ACT/18,,ATRIB(6).GE.ATRIB(1),L0;
;UHTS W/ 850 HRS
          ACT/20,ATRIB(6),ATRIB(6).LT.ATRIB(1),CNTR;#EXP UHTS

L0      GOON,1;
          ACT/22,ATRIB(1),,G4;

;COMPUTES # OF MONTHS INTO TOUR THAT PILOT
;REACHES EXPERIENCED STATUS (300 HRS)
PQPX  ASSIGN,EXCS=ATRIB(5)-300.,
                 REQD=ATRIB(2)-EXCS,
                 ATRIB(6)=REQD/15.,1;
```

```
;PQPS WHO ATTRIT
        ACT/24,,ATRIB(6).GE.ATRIB(1),L1;PQP NEVER EXP
;PQPS W/ 300 HRS
        ACT/26,ATRIB(6),ATRIB(6).LT.ATRIB(1),CNTR;#EXP PQPS

;COUNTS EXPERIENCED PILOTS, COMPUTES PERCENT EXP
CNTR      ASSIGN,EXPD=EXPD+1.,
             PERC=EXPD/ACTV,
;COMPUTES TIME REMAINING IN TOUR
             ATRIB(1)=ATRIB(1)-ATRIB(6),
             ATRIB(6)=0.0,1;
        ACT/28,ATRIB(1),,G4;TOTAL EXP

L1      GOON,1;
        ACT/30,ATRIB(1),,G4;PQP ONLY

G4      GOON,1;
;EXPERIENCED PILOTS WHO ATTRIT
        ACT/32,,ATRIB(7).EQ.1.0.AND.ATRIB(6).EQ.0.0,DEPT;
;NEVER EXPERIENCED PILOTS WHO ATTRIT
        ACT/34,,ATRIB(7).EQ.1.0.AND.ATRIB(6).NE.0.0,LOSE;
;EXPERIENCED UHTS WHO OWE PAYBACK FOR TRAINING
        ACT/36,,ATRIB(3).EQ.0.0.AND.ATRIB(5).LT.1000.,PAY0;
;EXPERIENCED PQPS WHO OWE PAYBACK FOR TRAINING
        ACT/38,,ATRIB(3).EQ.1.0.AND.ATRIB(5).LT.XX(11),PAY1;
;PILOTS W/ MORE THAN 11 YRS SERVICE
        ACT/40,,ATRIB(4).GE.132.,QUE4;SKIP JOB3
;EVERYONE ELSE
        ACT/42,,,QUE3;TO JOB2

;ASSIGN SUBSEQUENT FLYING TOUR LENGTHS TO UHTS
PAY0    ASSIGN,ATRIB(1)=TRIAG(XX(8),XX(9),XX(10),1),1;
        EVENT,1,1;
          ACT,,,L0;

;ASSIGN SUBSEQUENT FLYING TOUR LENGTHS TO PQPS
PAY1    ASSIGN,ATRIB(1)=TRIAG(XX(8),XX(9),XX(10),1),1;
        EVENT,1,1;
          ACT,,,L1;

;7 TO 11 YEAR GROUP
QUE3    QUEUE(3);
          ACT(100)/44;TO G5
G5      GOON,1;
;# OF BLOCKED COCKPITS FOR 7-11 YR GROUP
          ACT,,NNACT(46).LT.XX(12),FLY2;FLY2
;OTHERWISE TO NON-FYING JOB
          ACT,,,NOF2;NOFLY2

;FLYING ASSIGNMENTS FOR 7-11 YR GROUP
FLY2    ASSIGN,ATRIB(1)=TRIAG(XX(8),XX(9),XX(10),1),1;
```

```
        EVENT,1,1;
          ACT/46,ATRIB(1),,G6;FLY2

;NON-FLYING ASSIGNMENTS FOR 7-11 YR GROUP
NOF2  ASSIGN,ATRIB(1)=TRIAG(30.,36.,42.,1),
              ACTV=ACTV-1.,
              EXPD=EXPD-1.,
              PERC=EXPD/ACTV,1;
        EVENT,2,1;

          ACT/48,ATRIB(1);NOFLY2
        ASSIGN,ACTV=ACTV+1.,
              EXPD=EXPD+1.,
              PERC=EXPD/ACTV,1;

G6      GOON,1;
;ATTRITION
        ACT/50,,ATRIB(7).EQ.1.0,DEPT;SEPAR3
;LESS THAN 11 YRS TIME IN SERVICE
        ACT/52,,ATRIB(4).LT.132.,QUE3;<11YRS GATE TIME
;EVERYONE ELSE
        ACT/54;TO JOB 3

; 12-17 YR GROUP
QUE4  QUEUE(4);
        ACT(120)/56;TO G7
G7      GOON,1;
;BLOCKED COCKPITS FOR 12-17 YR GROUP
        ACT,,NNACT(58).LT.XX(12),FLY3;FLY3
        ACT,,,NOF3;NOFLY3

FLY3  ASSIGN,ATRIB(1)=TRIAG(XX(8),XX(9),XX(10),1),1;

        EVENT,1,1;
          ACT/58,ATRIB(1),,G8;FLY3

NOF3  ASSIGN,ATRIB(1)=TRIAG(30.,36.,42.,1),
              ACTV=ACTV-1.,
              EXPD=EXPD-1.,
              PERC=EXPD/ACTV,1;
        EVENT,2,1;
          ACT/60,ATRIB(1);NOFLY3
        ASSIGN,ACTV=ACTV+1.,
              EXPD=EXPD+1.,
              PERC=EXPD/ACTV,1;

G8      GOON,1;
          ACT/62,,ATRIB(7).EQ.1.0,DEPT;SEPAR4
          ACT/64,,ATRIB(4).LT.204.,QUE4;<17YRS
          ACT/66;LASTJOB
```

```
; 18-20+ YR GROUP
QUE5   QUEUE(5);
         ACT(150)/68;TO G9
G9     GOON,1;
;# BLOCKED COCKPITS FOR SENIOR OFFICERS
         ACT,,NNACT(70).LT.0,FLY4;FLY4
         ACT,,,NOF4;NOFLY4

FLY4   ASSIGN,ATRIB(1)=TRIAG(18.,24.,30.,1),1;

       EVENT,1,1;
         ACT/70,ATRIB(1),,G10;FLY4

NOF4   ASSIGN,ATRIB(1)=TRIAG(30.,36.,42.,1),
               ACTV=ACTV-1.,
               EXPD=EXPD-1.,
               PERC=EXPD/ACTV,1;
       EVENT,2,1;
         ACT/72,ATRIB(1);NOFLY4
       ASSIGN,ACTV=ACTV+1.,
               EXPD=EXPD+1.,
               PERC=EXPD/ACTV,1;

G10    GOON,1;
         ACT/74,,ATRIB(7).EQ.1.0.AND.ATRIB(4).LT.240.,DEPT;
         ACT/76,,ATRIB(4).LT.240.,QUE5;<20YRS
;RETIREES
         ACT/78;RETIRE
       ASSIGN,EXPD=EXPD-1.,
               ACTV=ACTV-1.,
               PERC=EXPD/ACTV,1;
       COLCT,ALL,RETIREES,,1;
       TERM;

; PILOTS LOST BEFORE BECOMING EXPERIENCED
LOSE   ASSIGN,ACTV=ACTV-1.,
               PERC=EXPD/ACTV,1;
       ACT/80,,,COLL;NEVER EXPD

;EXPERIENCED PILOTS WHO SEPARATE
DEPT   ASSIGN,EXPD=EXPD-1.,
               ACTV=ACTV-1.,
               PERC=EXPD/ACTV,1;
COLL   COLCT,ALL,SEPARATED,,1;
       TERM;
       END;

INIT,0,900;
SIMULATE;
;THIS IS JUST ONE LINE OF THE DESIGN MATRIX
     -1           -1           -1           -1           -1
FIN;
```

Appendix D: FORTRAN Code

```fortran
      DIMENSION NSET(20000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
     1MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
     2SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(20000)
      COMMON/UCOM1/RET(25)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=20000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      OPEN(11,STATUS='NEW',FILE='THESIS.DAT'
     *    ,FORM='FORMATTED')
      OPEN(12,STATUS='NEW',FILE='SAS.DAT'
     *    ,FORM='FORMATTED')
      CALL SLAM
      STOP
      END


      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
     1MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
     2SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(20000)
      COMMON/UCOM1/RET(25),XINP,UHT,TRL,PAY,BLK,HRS
      EQUIVALENCE (XX(1),EXPD),(XX(2),ACTV)

C     READ AND INITIALIZE THE VARIABLES
C       READ(NCRDR,*)XX(6),XX(7),XX(9),XX(11),XX(12)

C     CODED VARIABLES
      XINP=XX(6)
      UHT=XX(7)
      TRL=XX(9)
      PAY=XX(11)
      BLK=XX(12)
      HRS=-1.

C     UNCODED FOR SLAM
      XX(6)=-.5*XX(6)+1.5
      XX(7)=.25*XX(7)+.25
      XX(9)=12.*XX(9)+48.
      XX(8)=XX(9)-6.0
      XX(10)=XX(9)+6.0
      XX(11)=125.*XX(11)+625.
      XX(12)=(15.*XX(12)+15.)/2.
      XX(13)=10.
```

```
C        SET UP RETENTION RATES FOR YEAR OF SERVICE 1-20
         DATA
         RET/1.0,.986,1.0,.958,.974,.971,.909,.963,.955
         1,.977,.875,.886,.892,1.0,1.0,.983,1.0,.955,.906,.745,
         2.521,.667,1.0,.778,.5/

         RETURN
         END




         SUBROUTINE EVENT(I)
         COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II
         1,MFA,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE
         2,SS(100),SSL(100),TNEXT,TNOW,XX(100)
         COMMON QSET(20000)
         COMMON/UCOM1/RET(25),NB1,NB2,NB3

         GO TO (1,2,3) I

C        FOR FLYING ASSIGNMENTS
  1      CALL FLYER
         RETURN

C        FOR NON-FLYING ASSIGNMENTS
  2      CALL NONFLY
         RETURN

C        TO CLEAR STAT ARRAYS AFTER 200 MONTHS
  3      CALL CLEAR
         RETURN
         END




         SUBROUTINE FLIER
         COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II
         1,MFA,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
         2SS(100),SSL(100),TNEXT,TNOW,XX(100)
         COMMON QSET(20000)
         COMMON/UCOM1/RET(25),NB1,NB2,NB3

C        TIME IN SERVICE IN YEARS
         ITIS=INT(ATRIB(4)/12.)
C        ASSIGNED TOUR LENGTH IN YEARS
         ITRL=INT(ATRIB(1)/12.)
C        DRAW FROM UNIFORM DISTRIBUTION
         PROB=UNFRM(0.0,1.0,1)
         XRET=1.0
         ATRIB(7)=0.0
C        FOR AS MANY YEARS AS TOUR, CHECK RETENTION
         DO 10 I=1,ITRL
```

```
      XRET=RET(ITIS+I)
C     IF TIME IN SERVICE EXCEEDS 25 YEARS, USE YR 25
C     RETENTION
      TEMP=ITIS+I
          IF(TEMP.GT.25)XRET=RET(25)
C     IF SEPARATING, COMPUTE FIGURES FOR SHORTENED TOUR
C     LENGTH
      IF(PROB.GT.XRET) THEN
          ATRIB(1)=I*12.
          ATRIB(4)=ATRIB(4)+ATRIB(1)
          ATRIB(2)=10.*ATRIB(1)
          ATRIB(5)=ATRIB(5)+ATRIB(2)
          ATRIB(7)=1.0
          GO TO 3
      ENDIF

C     IF NOT SEPARATING, COMPUTE FIGURES FOR ASSIGNED TOUR
 10   CONTINUE
      ATRIB(2)=10.*ATRIB(1)
      ATRIB(4)=ATRIB(4)+ATRIB(1)
      ATRIB(5)=ATRIB(5)+ATRIB(2)
  3   RETURN
      END




      SUBROUTINE NONFLY
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,
     1II,MFA,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE
     2,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(20000)
      COMMON/UCOM1/RET(25),NB1,NB2,NB3

      ITIS=INT(ATRIB(4)/12.)
      ITRL=INT(ATRIB(1)/12.)
      PROB=UNFRM(0.0,1.0,1)
      XRET=1.0
      ATRIB(7)=0.0
      DO 10 I=1,ITRL
        XRET=RET(ITIS+I)
        TEMP=ITIS+I
          IF(TEMP.GT.25)XRET=RET(25)
          IF(PROB.GT.XRET) THEN
            ATRIB(1)=I*12.
            ATRIB(4)=ATRIB(4)+ATRIB(1)
            ATRIB(7)=1.0
            GO TO 3
          ENDIF
 10   CONTINUE
      ATRIB(4)=ATRIB(4)+ATRIB(1)
  3   RETURN
      END
```

```fortran
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW
     1,II,MFA,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE
     2,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(20000)
      COMMON/UCOM1/RET(25),XINP,UHT,TRL,PAY,BLK,HRS
      EQUIVALENCE (XX(4),PERC),(XX(2),ACTV)
      TEMP=100*TTAVG(1)
C     WRITE UNCODED VARIABLES AND OUTPUT TO A FILE
      WRITE(11,100)XX(6),XX(7),XX(9),XX(11),XX(12),XX(13)
     1,TEMP,TTAVG(3)
C     WRITE CODED VARIABLES AND OUTPUT TO A FILE
      WRITE(12,200)XINP,UHT,TRL,PAY,BLK,HRS,TEMP,TTAVG(3)

 100  FORMAT(8(1X,F6.2,1X))
 200  FORMAT(6(2X,F5.2,1X),2(1X,F5.1,1X))

      RETURN
      END
```

Factor Screen: 2^6 Full Factorial

INP	UHT	TRL	PAY	BLK	HRS	EXP	TOT
-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	68.4	67.5
1.0	-1.0	-1.0	-1.0	-1.0	-1.0	68.3	136.4
-1.0	1.0	-1.0	-1.0	-1.0	-1.0	42.6	85.0
1.0	1.0	-1.0	-1.0	-1.0	-1.0	43.7	167.0
-1.0	-1.0	1.0	-1.0	-1.0	-1.0	62.3	56.9
1.0	-1.0	1.0	-1.0	-1.0	-1.0	62.4	113.9
-1.0	1.0	1.0	-1.0	-1.0	-1.0	42.9	86.1
1.0	1.0	1.0	-1.0	-1.0	-1.0	42.6	169.6
-1.0	-1.0	-1.0	1.0	-1.0	-1.0	69.2	69.2
1.0	-1.0	-1.0	1.0	-1.0	-1.0	69.5	140.2
-1.0	1.0	-1.0	1.0	-1.0	-1.0	43.9	85.9
1.0	1.0	-1.0	1.0	-1.0	-1.0	44.7	171.7
-1.0	-1.0	1.0	1.0	-1.0	-1.0	79.8	106.5
1.0	-1.0	1.0	1.0	-1.0	-1.0	79.8	212.1
-1.0	1.0	1.0	1.0	-1.0	-1.0	55.3	108.7
1.0	1.0	1.0	1.0	-1.0	-1.0	55.6	217.2
-1.0	-1.0	-1.0	-1.0	1.0	-1.0	78.0	96.5
1.0	-1.0	-1.0	-1.0	1.0	-1.0	74.1	165.0
-1.0	1.0	-1.0	-1.0	1.0	-1.0	57.7	114.4
1.0	1.0	-1.0	-1.0	1.0	-1.0	51.5	200.4
-1.0	-1.0	1.0	-1.0	1.0	-1.0	75.2	85.2
1.0	-1.0	1.0	-1.0	1.0	-1.0	70.1	143.2
-1.0	1.0	1.0	-1.0	1.0	-1.0	58.5	112.5
1.0	1.0	1.0	-1.0	1.0	-1.0	51.9	198.8
-1.0	-1.0	-1.0	1.0	1.0	-1.0	78.4	98.2
1.0	-1.0	-1.0	1.0	1.0	-1.0	75.0	171.2
-1.0	1.0	-1.0	1.0	1.0	-1.0	58.3	114.9
1.0	1.0	-1.0	1.0	1.0	-1.0	52.5	200.3
-1.0	-1.0	1.0	1.0	1.0	-1.0	82.5	122.6
1.0	-1.0	1.0	1.0	1.0	-1.0	81.4	229.8
-1.0	1.0	1.0	1.0	1.0	-1.0	61.7	124.9
1.0	1.0	1.0	1.0	1.0	-1.0	58.8	232.9

-1.0	-1.0	-1.0	-1.0	-1.0	1.0	59.1	34.8
1.0	-1.0	-1.0	-1.0	-1.0	1.0	59.1	70.4
-1.0	1.0	-1.0	-1.0	-1.0	1.0	37.6	52.8
1.0	1.0	-1.0	-1.0	-1.0	1.0	38.5	102.9
-1.0	-1.0	1.0	-1.0	-1.0	1.0	74.9	56.9
1.0	-1.0	1.0	-1.0	-1.0	1.0	74.9	113.9
-1.0	1.0	1.0	-1.0	-1.0	1.0	57.8	78.2
1.0	1.0	1.0	-1.0	-1.0	1.0	57.6	155.6
-1.0	-1.0	-1.0	1.0	-1.0	1.0	79.0	68.3
1.0	-1.0	-1.0	1.0	-1.0	1.0	78.9	136.2
-1.0	1.0	-1.0	1.0	-1.0	1.0	52.1	67.7
1.0	1.0	-1.0	1.0	-1.0	1.0	53.9	138.1
-1.0	-1.0	1.0	1.0	-1.0	1.0	74.8	56.8
1.0	-1.0	1.0	1.0	-1.0	1.0	74.8	112.6
-1.0	1.0	1.0	1.0	-1.0	1.0	56.9	76.4
1.0	1.0	1.0	1.0	-1.0	1.0	57.5	151.7
-1.0	-1.0	-1.0	-1.0	1.0	1.0	77.9	64.6
1.0	-1.0	-1.0	-1.0	1.0	1.0	71.3	100.0
-1.0	1.0	-1.0	-1.0	1.0	1.0	60.5	82.5
1.0	1.0	-1.0	-1.0	1.0	1.0	51.8	136.0
-1.0	-1.0	1.0	-1.0	1.0	1.0	83.4	86.4
1.0	-1.0	1.0	-1.0	1.0	1.0	80.0	142.9
-1.0	1.0	1.0	-1.0	1.0	1.0	69.8	104.3
1.0	1.0	1.0	-1.0	1.0	1.0	64.8	183.4
-1.0	-1.0	-1.0	1.0	1.0	1.0	85.2	97.1
1.0	-1.0	-1.0	1.0	1.0	1.0	82.7	164.6
-1.0	1.0	-1.0	1.0	1.0	1.0	67.0	98.4
1.0	1.0	-1.0	1.0	1.0	1.0	61.7	167.2
-1.0	-1.0	1.0	1.0	1.0	1.0	83.5	86.6
1.0	-1.0	1.0	1.0	1.0	1.0	80.0	143.7
-1.0	1.0	1.0	1.0	1.0	1.0	69.7	105.6
1.0	1.0	1.0	1.0	1.0	1.0	64.5	182.2

2^3 Full-Factorial Design for Two-Factor Metamodels

INP	UHT	EXP	TOT
-1.00	-1.00	79.3	83.1
1.00	-1.00	76.7	146.3
-1.00	1.00	58.5	94.7
1.00	1.00	55.4	172.4
0.00	-1.00	78.1	104.8
0.00	1.00	56.2	120.4
-1.00	0.00	68.0	87.1
1.00	0.00	64.9	161.5

Appendix F: Graphs of ANOVA Assumptions

Factor Screen: EXP

PREDICTED VALUE
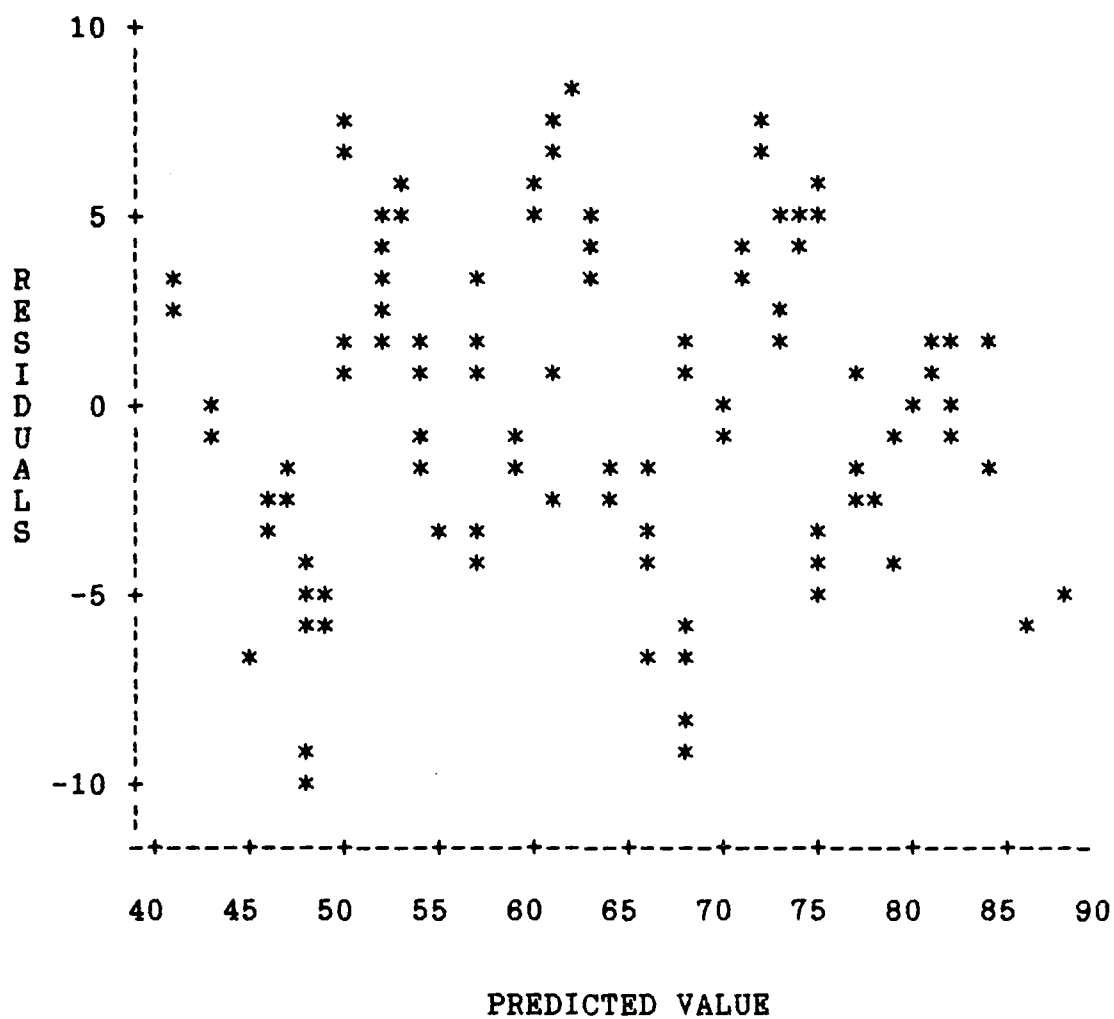
Normal Probability Plot: EXP

61
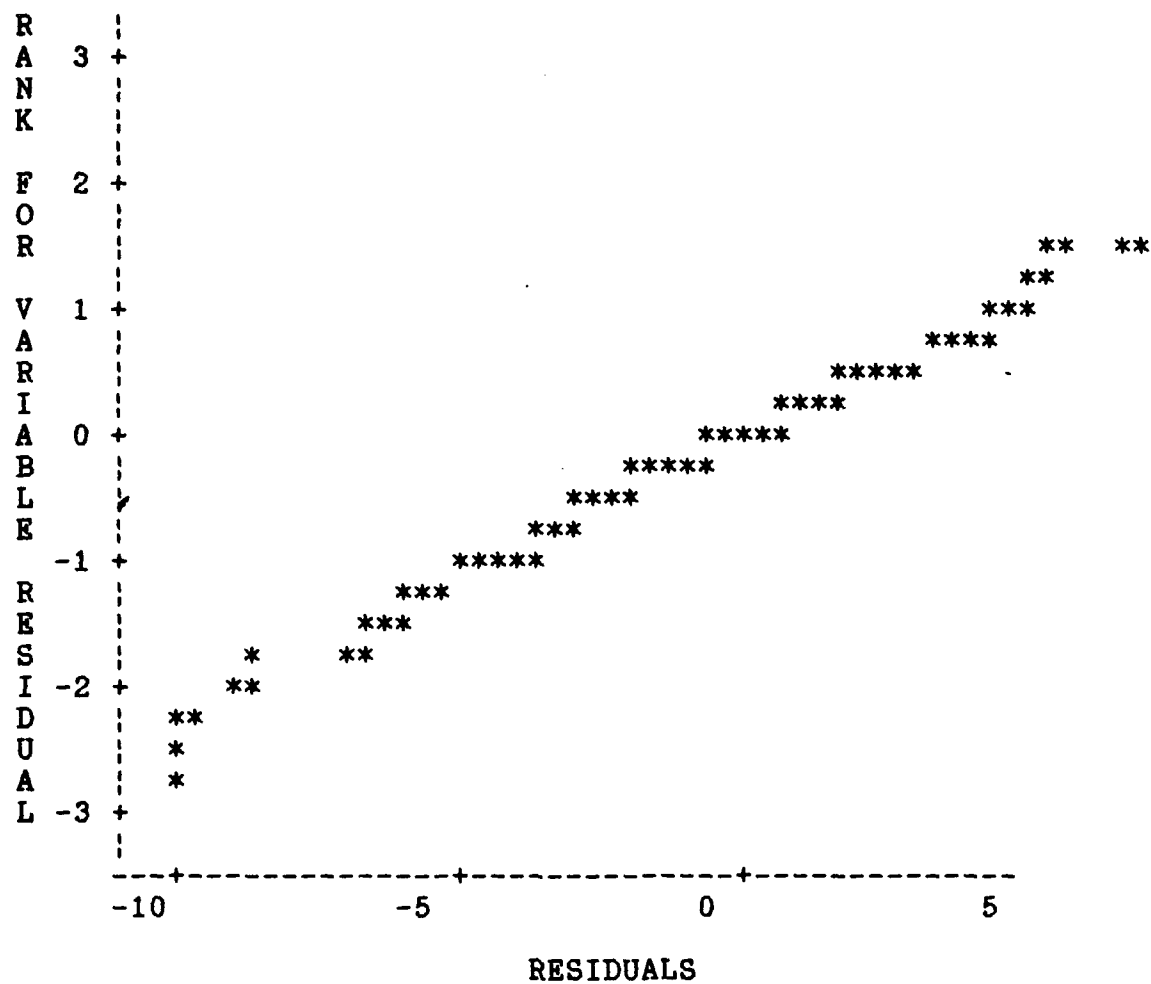
Factor Screen: TOT
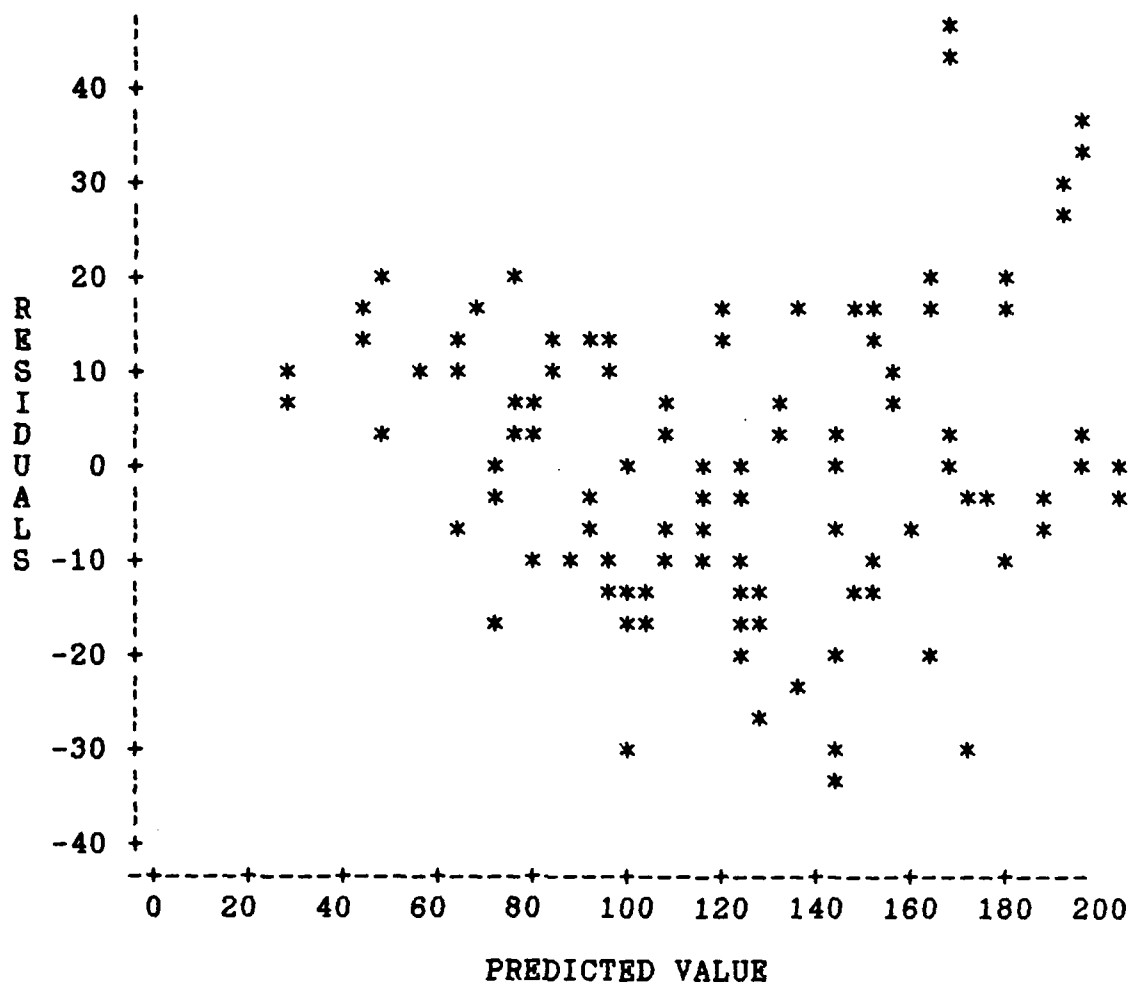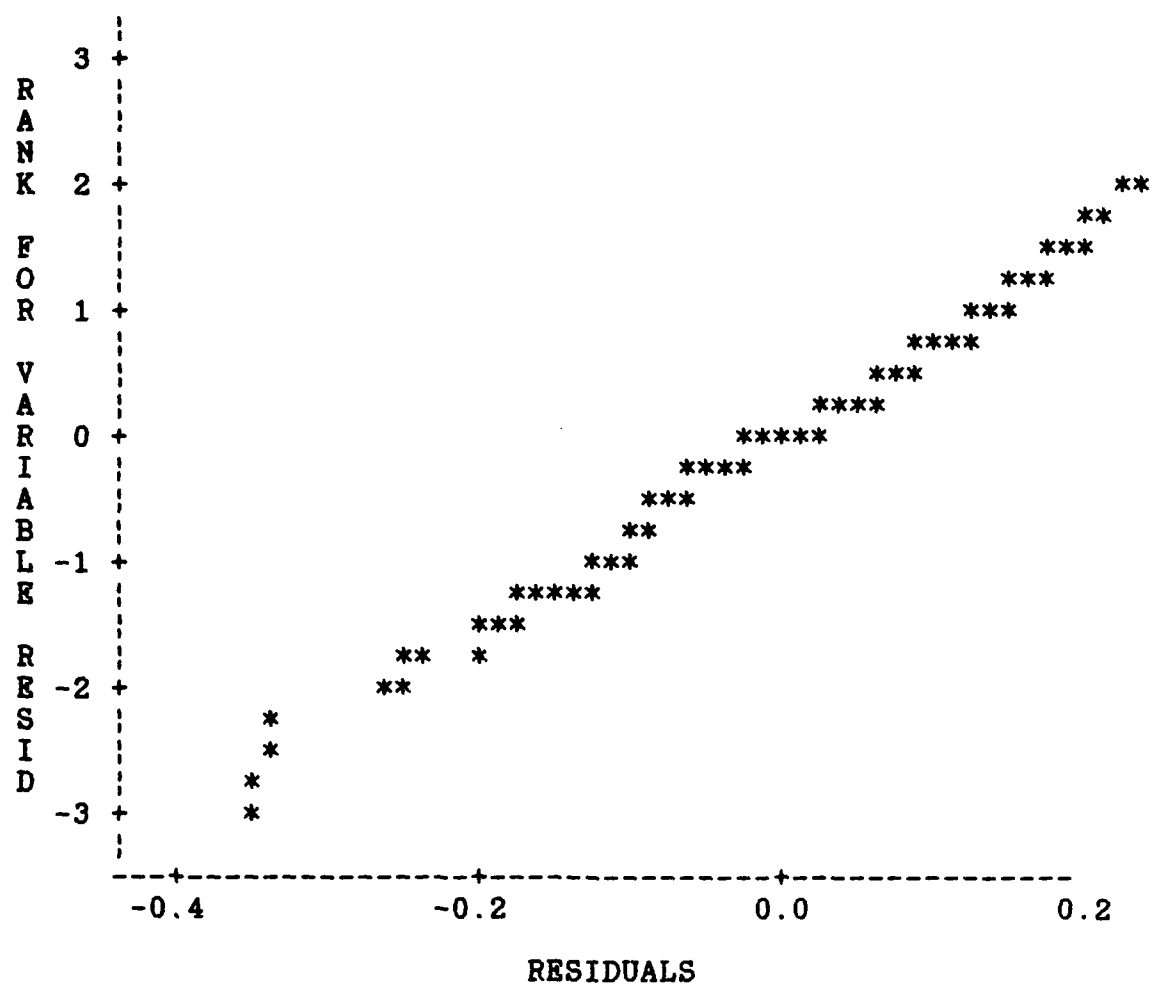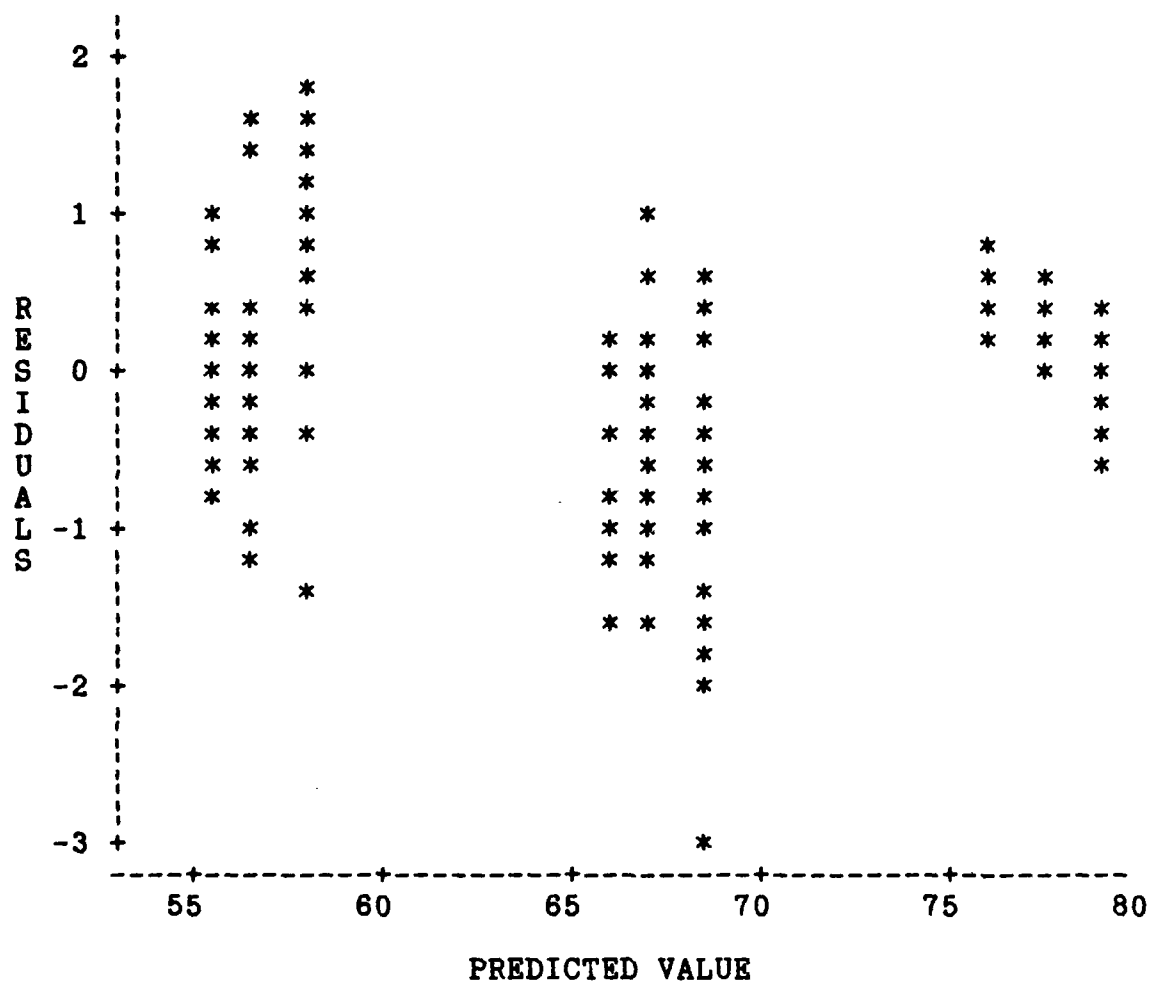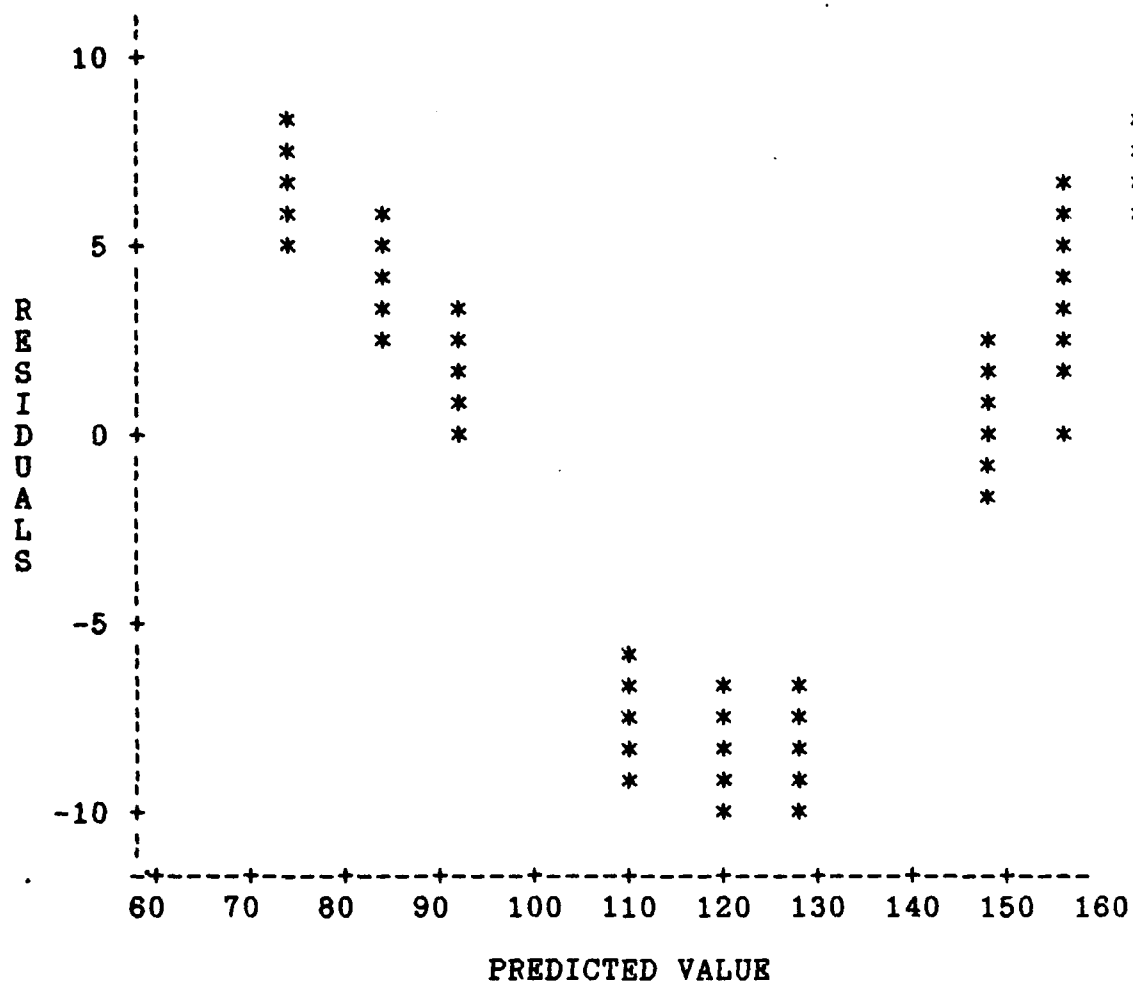
Factor Screen: ln(TOT)
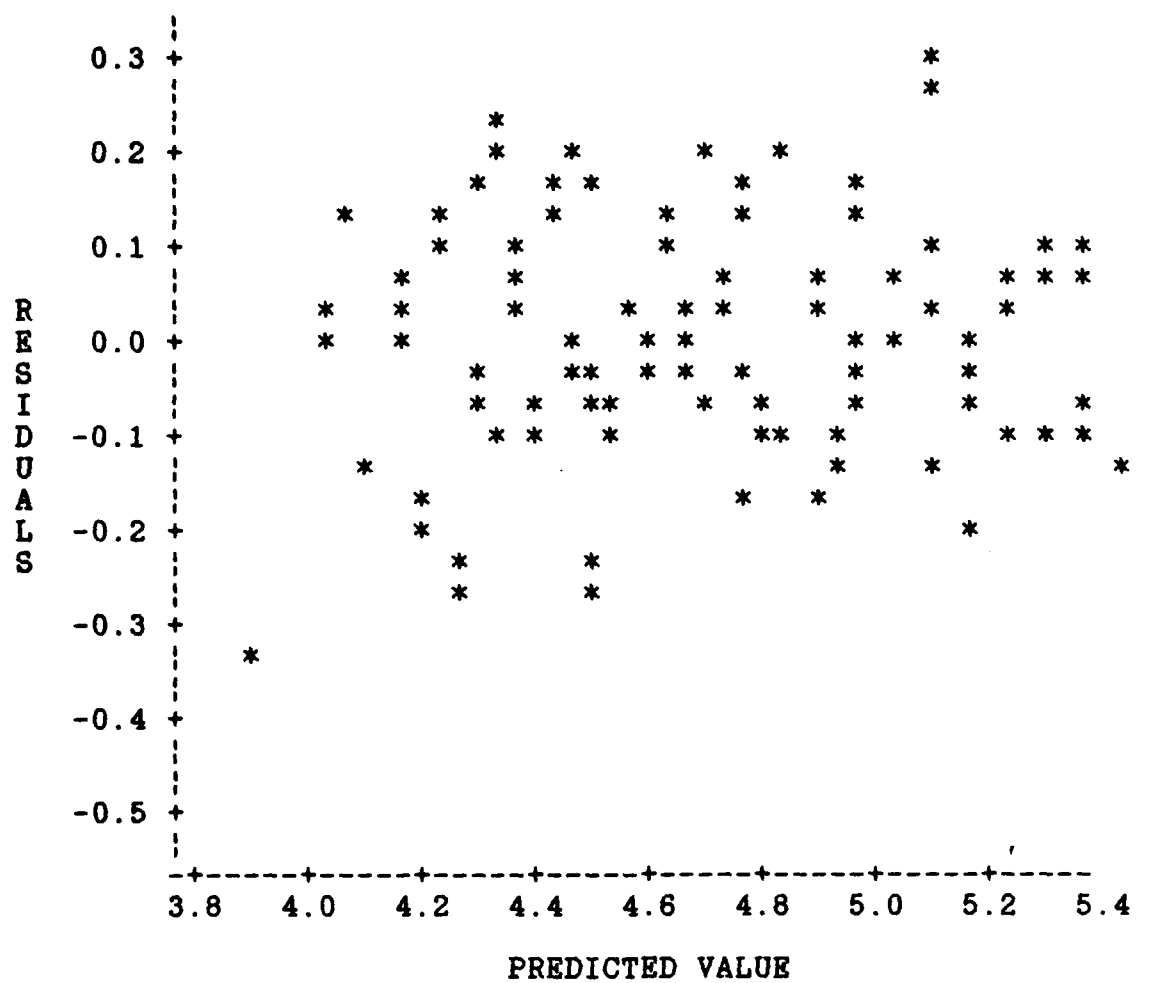
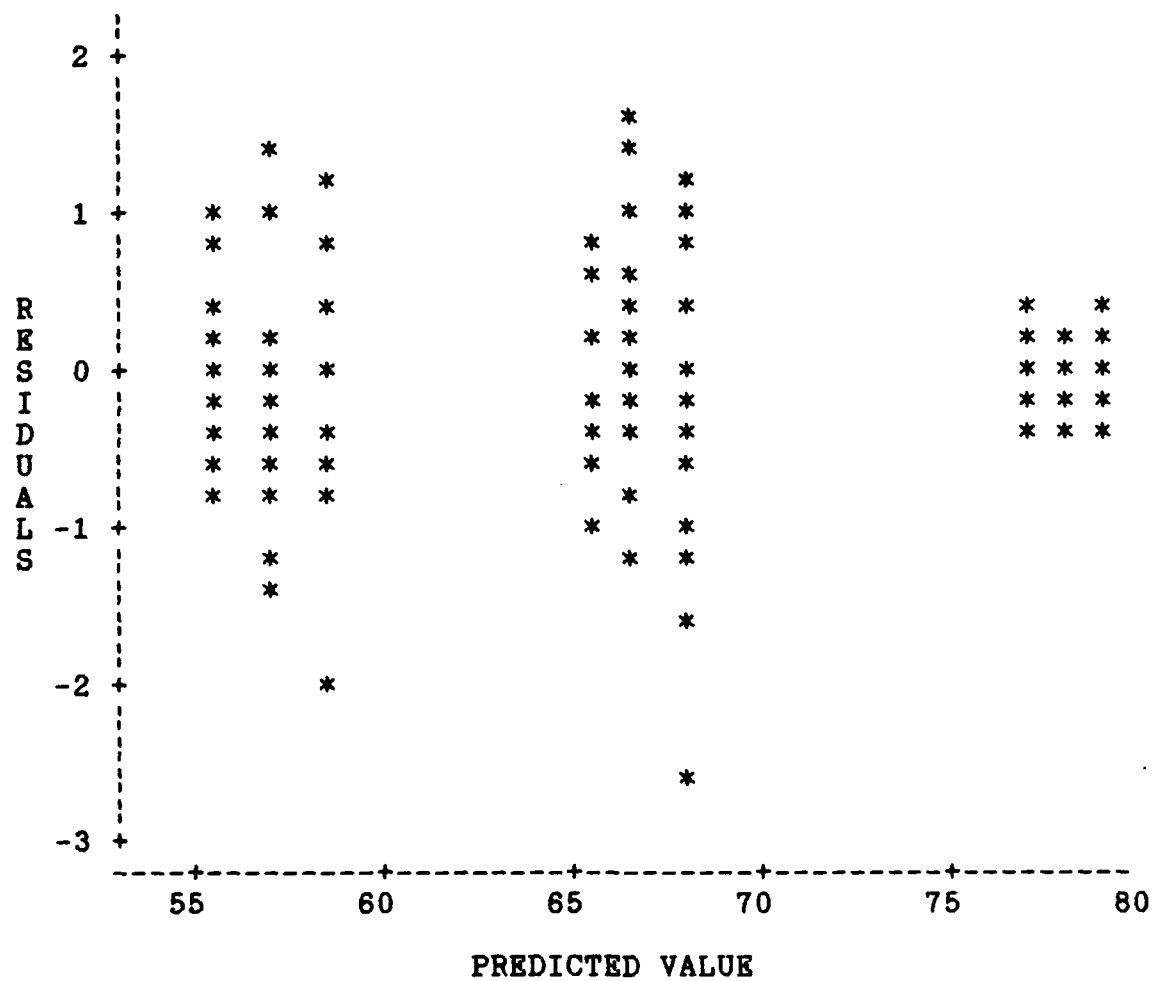Normal Probability Plot: ln(TOT)
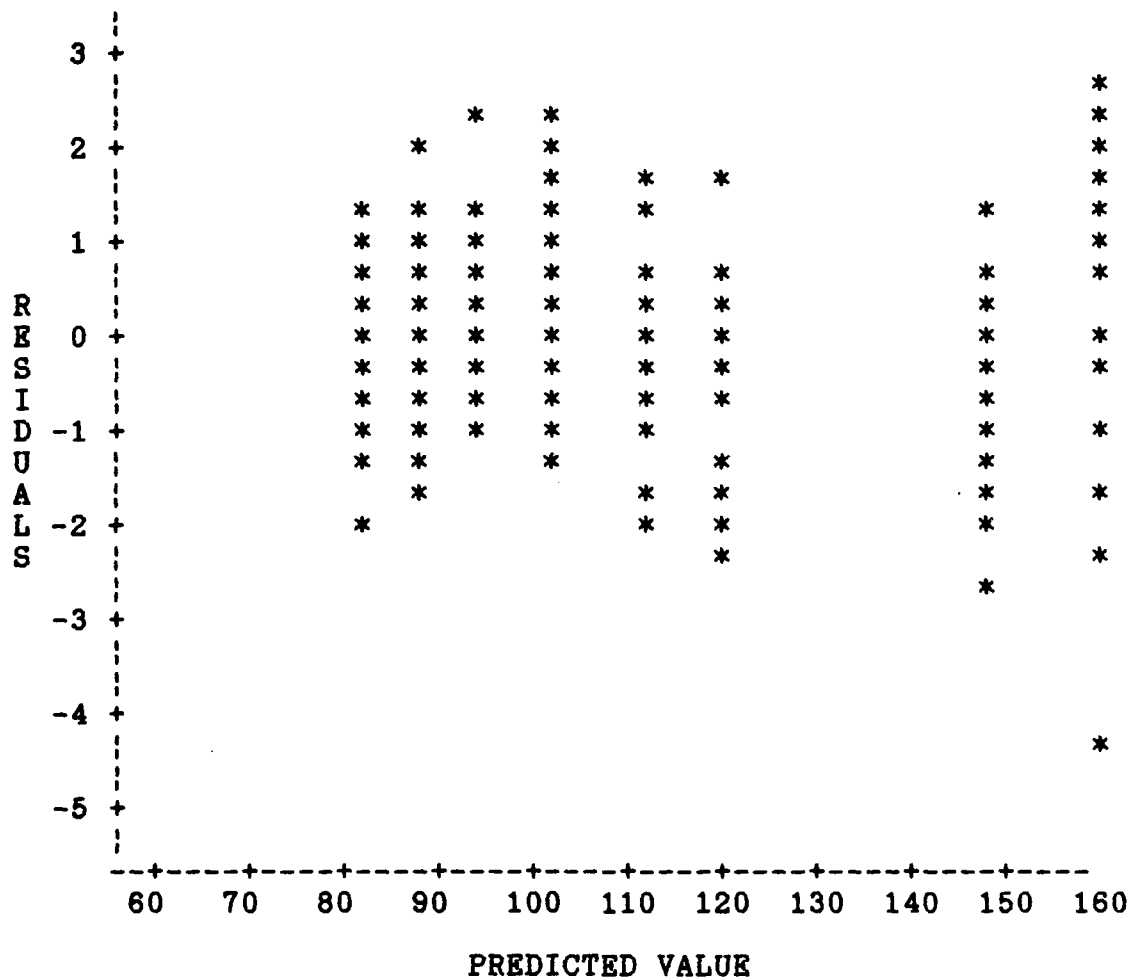
First-Order Metamodel: EXP
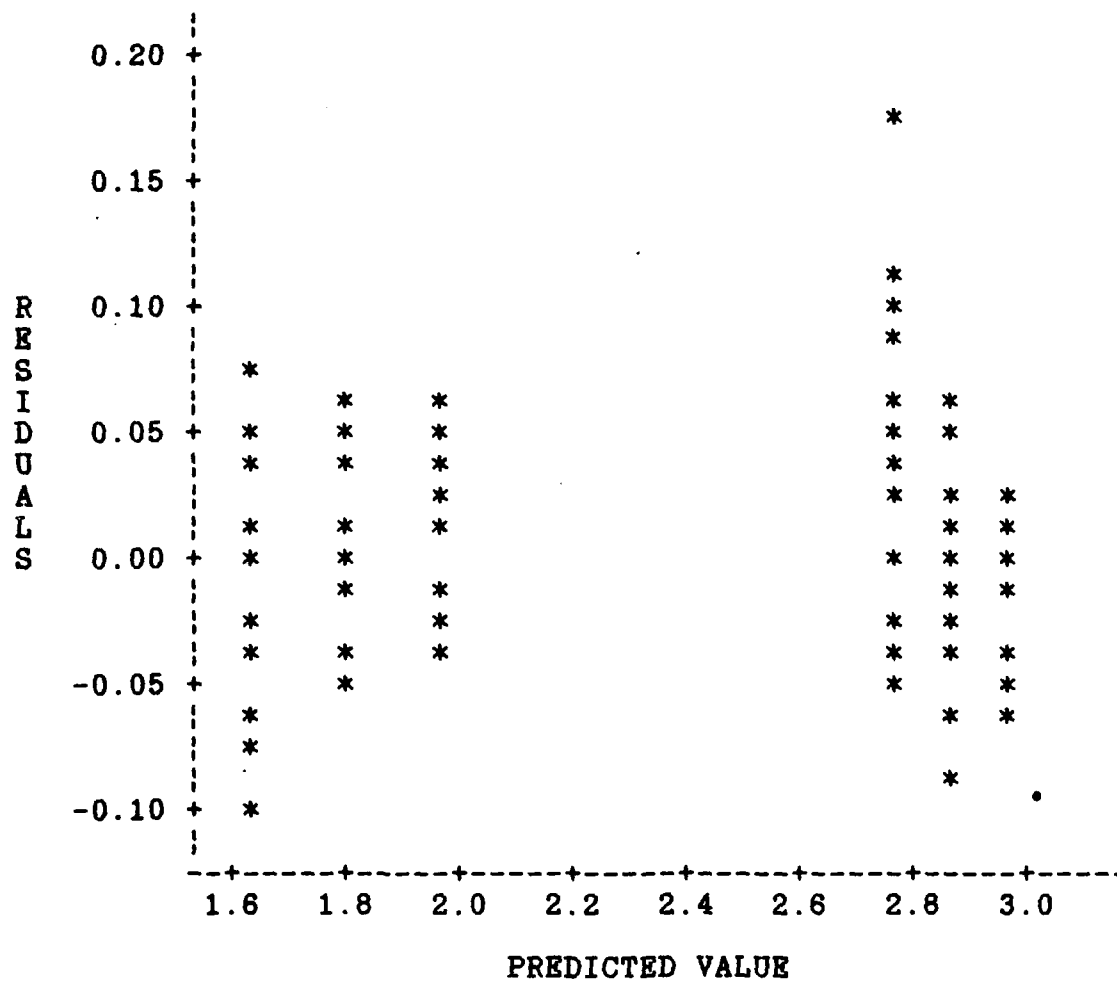
65

First-Order Metamodel: TOT
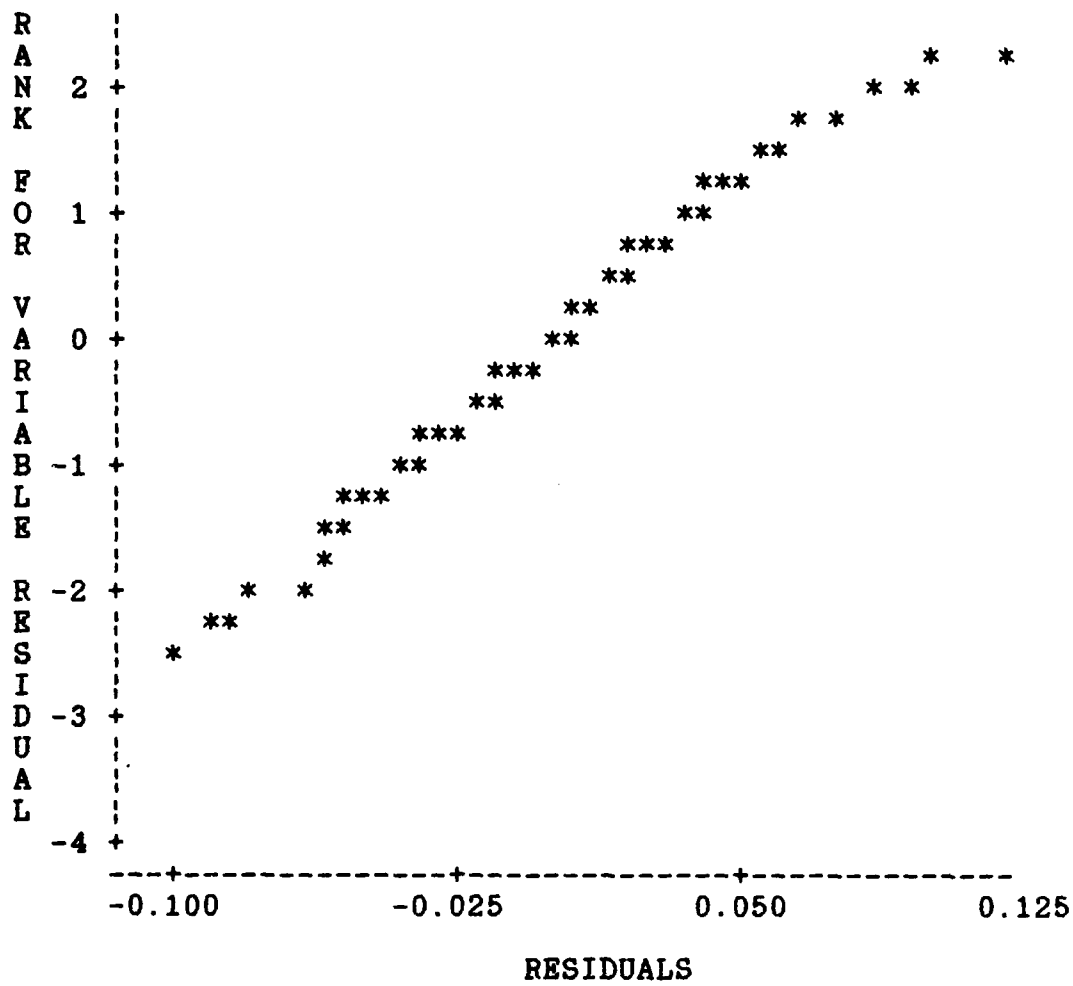
Second-Order Metamodel: EXP
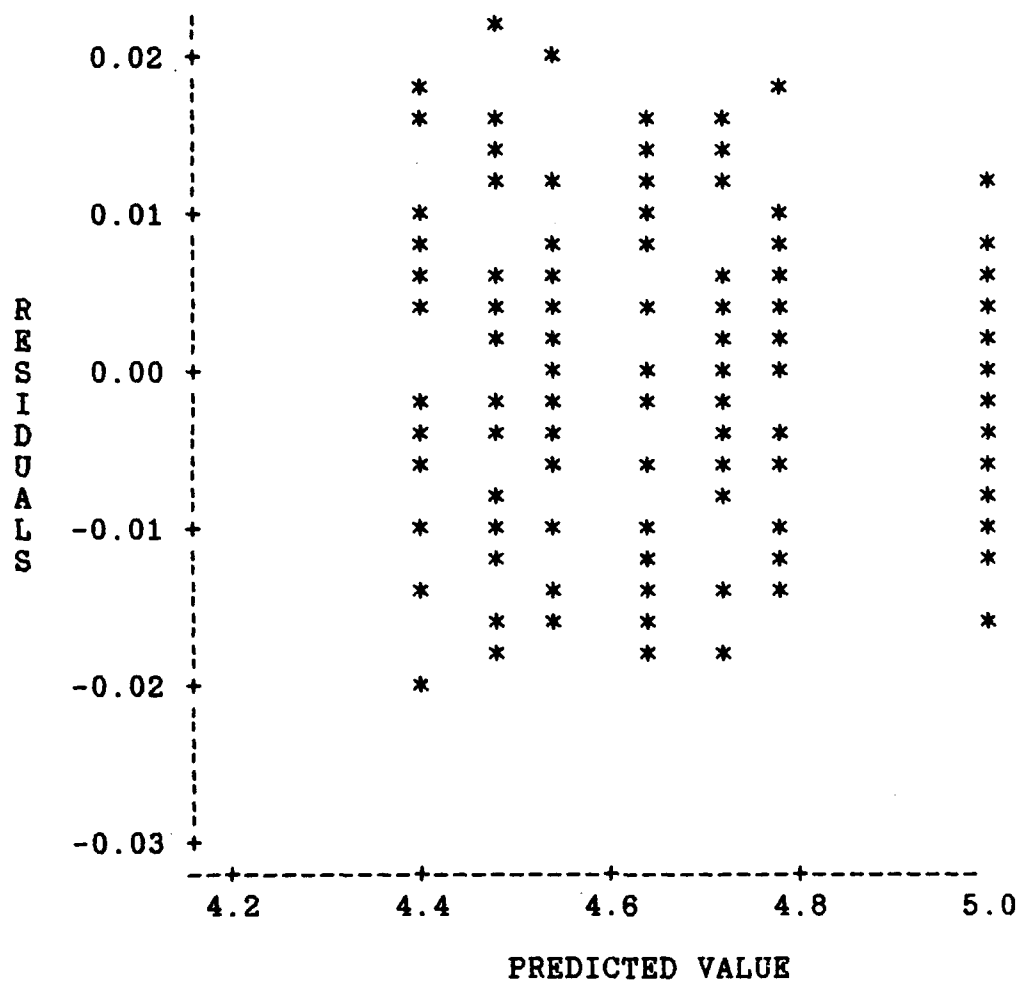
67

Second-Order Metamodel: TOT

68

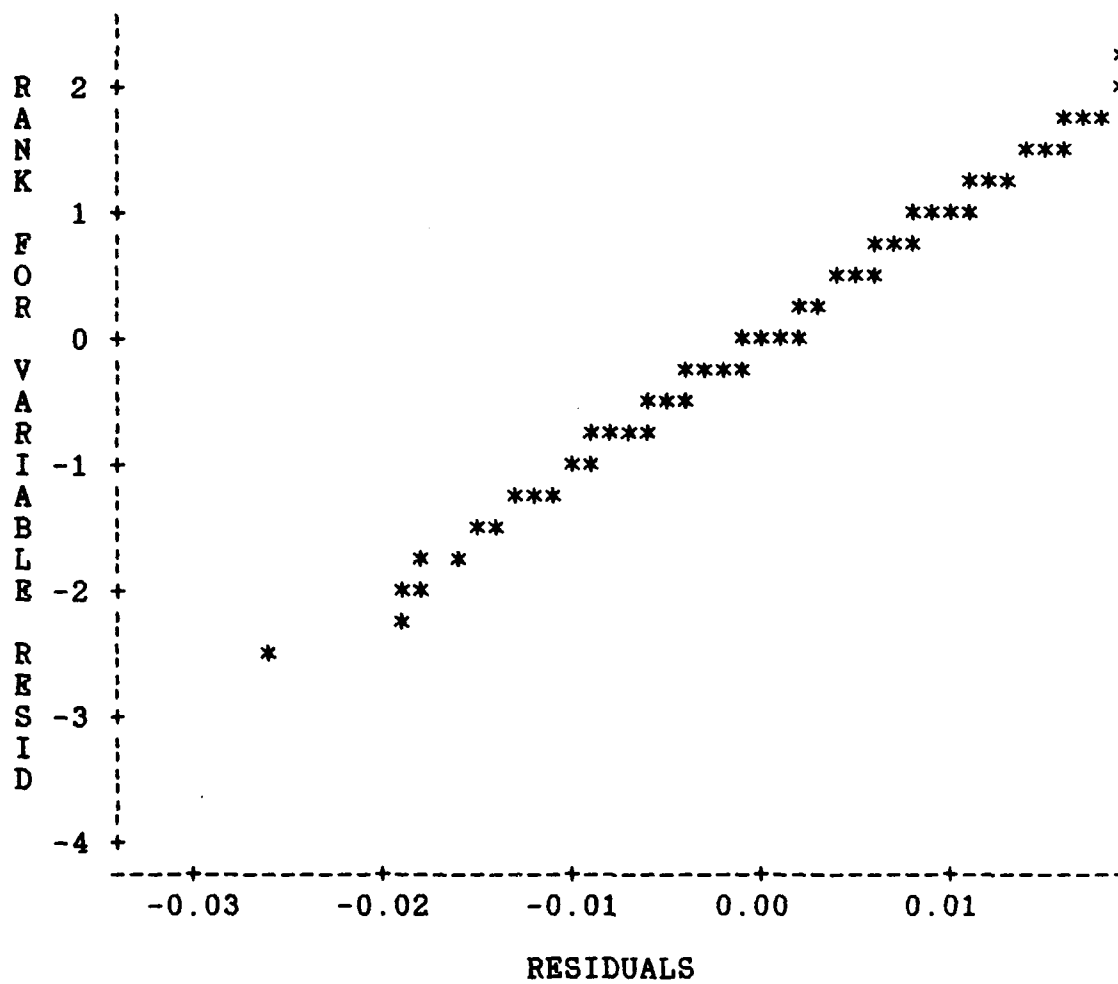Second-Order Metamodel: ln(84-EXP)

Normal Probability Plot: ln(84-EXP)

Second-Order Metamodel: ln(TOT)

Normal Probability Plot: ln(TOT)

Appendix G: Steady-State Graph

TIME	0	10	20	30	40	50	60	70	80	90
0.0000E+00	*					+				
0.5000E+01	*					+				
0.1000E+02	*					+				
0.1500E+02	*					+				
0.2000E+02	*					+				
0.2500E+02	*					+				
0.3000E+02	+		*			+				
0.3500E+02	+			*		+				
0.4000E+02	+			*		+				
0.4500E+02	+					+				
0.5000E+02	+			*		+				
0.5500E+02	+			*		+				
0.6000E+02	+				*	+				
0.6500E+02	+				*	+				
0.7000E+02	+				*	+				
0.7500E+02	+				*	+				
0.8000E+02	+				*	+				
0.8500E+02	+				*	+				
0.9000E+02	+					*+				
0.9500E+02	+					+*				
0.1000E+03	+					+	*			
0.1050E+03	+					+	*			
0.1100E+03	+					+	*			
0.1150E+03	+					+		*		
0.1200E+03	+					+		*		
0.1250E+03	+					+		*		
0.1300E+03	+					+		*		
0.1350E+03	+					+		*		
0.1400E+03	+					+		*		
0.1450E+03	+					+		*		
0.1500E+03	+					+		*		
0.1550E+03	+					+		*		
0.1600E+03	+					+		*		
0.1650E+03	+					+	*			
0.1700E+03	+					+	*			
0.1750E+03	+					+	*			
0.1800E+03	+					+	*			
0.1850E+03	+					+	*			
0.1900E+03	+					+	*			
0.1950E+03	+					+	*			
0.2000E+03	+					+	*			
0.2050E+03	+					+	*			
0.2100E+03	+					+	*			
0.2150E+03	+					+	*			
0.2200E+03	+					+	*			
0.2250E+03	+					+	*			
0.2300E+03	+					+	*			

Bibliograhy

Akam, Alan and Fred Nordhauser. <u>A Conceptual View of the Officer Procurement Model (TOPOS)</u>. June 1971-July 1974. Contract F41609-72-C-0042. Lackland AFB TX: HQ Air Force Human Resources Laboratory, July 1974 (AD-A001577).

Aronson, Jay E., and G. Thompson. "The Solution of Multiperiod Personnel Planning Problems by the Forward Simplex Method," <u>Large Scale Systems</u>, 9: 129-139 (1985).

Bauer, Kenneth W. Response Surface Methodology class notes (OPER 7.50). School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, Summer 1988.

Beattie, Major Daniel, Helicopter Resource Manager. Telephone interview. HQ AFMPC, Randolph AFB TX, 15 April 1988.

Box, G.E.P. and D.W. Behnken. "Some New Three Level Designs for the Study of Quantitative Variables," <u>Technometrics</u>, 2: 455-475, (November 1960).

Charnes, A. <u>et al</u>. <u>Studies in Manpower Planning</u>. 1972. Office of Civilian Manpower Management, U.S. Navy, Washington DC (AD-A066952).

Charpie, Kenneth E. <u>An Analysis of Chronic Personnel Shortages in the B-52 Radar Navigator Career Field</u>. MS thesis, AFIT/GST/ENS/87M-4. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1987.

Clark, Thomas D., Jr., and Kevin Lawson. "The Rotation and Assignment of Imbalanced Air Force Specialties: A Policy Analysis Model," <u>Simulation</u>, 43: 41-48 (July 1984).

Davie, Lt Col Don. Telephone interview. HQ USAF/DPXXO, Washington, D.C. 7 April 1988.

Department of the Air Force. <u>U.S. Air Force Helicopter Aircrew Training</u>. AFR 51-2. Washington DC: HQ USAF, June, 1984.

Department of the Air Force. <u>Officer Personnel: Officer Assignments</u>. AFR 36-20. Washington DC: HQ USAF, May 1987.

Department of the Air Force. Rated Management Document, Volume I. Washington DC: HQ USAF, 23 April 1987.

Forrester, Jay W. "System Dynamics: Future Opportunities," TIMS Studies in the Management Sciences, 14, edited by A. Legasto, Jr. et al. New York: North-Holland Publishing Company, 1980.

Hillier, Frederick S. and Gerald J. Lieberman. Introduction to Operations Research (Fourth Edition). Oakland CA: Holden-Day, 1986.

Jaquette, D.L. et al. An Analytic Review of Personnel Models in the Department of Defense. Report R-1920-ARPA. Arlington VA: Defense Advanced Research Projects Agency, September 1977 (AD-A045829).

Kelton, W. David and Averill M. Law. Simulation Modeling and Analysis. New York: McGraw-Hill, 1982.

Kleinman, Samuel and Karen Goudreau. An Evaluation of the Navy's URL Officer Accession Program, Report Number CNS-1096. Center for Naval Analyses, Arlington VA, September 1977 (AD-A057 213).

Knight, Jon M. The Aggregate Pilot Pipeline Model. Technical report, AFIT TR 78-6. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, November 1976 (AD-A064053).

Lawson, Kevin L. The Rotation/Assignment System of Imbalanced Air Force Specialty Codes Within Air Force Communications Command: A System Dynamics Model and Analysis. MS thesis, AFIT/GOR/OS/82D-8. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1982 (AD-A124779).

Leupp, H.A. Navy Group VIII (SEABEE) Enlisted Personnel Simulation Model. Stinger System Tactical Memorandum Number 69-3. Port Hueneme CA, SEABEE Systems Engineering Office Systems Analysis Group, August 1979 (AD-A772083).

Liang, Timothy T. and Theodore J. Thompson. "Applications and Implementation, A Large Scale-Personnel Assignment Model for the Navy," Decision Sciences, 18 No. 2: 234-249 (Spring 1987).

Litko, Joseph R. and Ronald E. Travis. A Dynamic Computer Model to Examine Selected Effects of 304XX Career Field Consolidation. MS Thesis, AFIT/LSH. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1982.

Looper, Larry T. Career Area Rotational Model (CAROM): Historical Overview of Technique and Utilization. AFHRL-TR-78-97. Brooks AFB TX: Occupational and Manpower Research Division, April 1979 (AD-A068 820).

Marcussen, Major Steve, Training Officer. Telephone interview. HQ 23rd AF/DOT, Hurlburt AFB FL, 20 April 1988.

Montgomery, D.C. Design and Analysis of Experiments (Second Edition). New York: John Wiley & Sons, 1984.

O'Conner, F.E. Aviation Officer Requirements Study. Contract N00014-81-0368. Arlington VA: The Office of Naval Research, 31 May 1982 (AD-A117920).

Olson, Major Mark S. A Network Approach to Rated Office Gate Management. MS thesis, AFIT/GOR/ENS/87D-13. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1987.

Page, Major Kenneth M. "U.S. Air Force Special Operations: Charting a Course for the Future." Airpower Journal, Fall, 1987. Washington, D.C: U.S. Government Printing Office, 1987.

Percich, David M. Modeling the Permanent Change of Station Moving Costs of Strategic Airlift Pilots. MS thesis, AFIT/GOR/ENS/87D-15. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1987 (AD-A189751).

Pritsker, R. Alan. Introduction to Simulation and SLAM II (Third Edition). New York: Halsted Press, 1986.

SAS Institute, Inc. SAS User's Guide: Statistics. Cary NC: SAS Institute, Inc., 1985.

Schrage, Linus. Linear, Integer, and Quadratic Programming with LINDO (Third Edition). Palo Alto CA: The Scientific Press, 1986.

Siverd, Samuel J., and Gerald L. Thompson. Ratio Goal Programming for Personnel Assignments. Contract N00014-75-C-0621. Carnegie-Melon University, Pittsburgh PA, September 1979 (AAD-A075220).

Thompson, Gerald L. <u>A Network Transshipment Model for Manpower Planning and Design</u>. Contract N00014-76-C-0932. Carnegie-Melon University, Pittsburgh PA, April 1978 (AD-A064345).

VITA

Capt John McKoy, ████████████████████████
████████████████████████████████████ He attended
Indian Springs High School, near Birmingham, Alabama, and
then the US Air Force Academy, graduating in 1980 with a
Bachelor of Science degree in business management. After
completing undergraduate helicopter training in 1981, Capt
McKoy flew the UH-1N helicopter while stationed at Fairchild
AFB, Washington, and Andrews AFB, Maryland. He entered the
Air Force Institute of Technology in June, 1987.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
UNCLASSIFIED	

2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT
	APPROVED FOR PUBLIC RELEASE;
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	DISTRIBUTION UNLIMITED JLM

4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
AFIT/GOR/ENS/88D-14	

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
School of Engineering	AFIT/ENS	

6c. ADDRESS (City, State, and ZIP Code)	7b. ADDRESS (City, State, and ZIP Code)
Air Force Institute of Technology (AU) Wright-Patterson AFB, Ohio 45463-6583	

8a. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AF Military Personnel Center	AFMPC/DPMYAP	

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
AFMPC/DPMYAP Randolph AFB, Texas				

11. TITLE (Include Security Classification)

MODELING THE PAVE LOW HELICOPTER PILOT CAREER FIELD

12. PERSONAL AUTHOR(S)
John C. McKoy, Capt, USAF

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MS Thesis	FROM _____ TO _____	1988 December	79

16. SUPPLEMENTARY NOTATION

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Computer Simulation, Military Personnel, Manpower, Simulation, Theses, (SDW)
12	4		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis presents a career model of the USAF Pave Low helicopter pilot force. A SLAM II computer simulation was developed to permit experimentation with key decision variables. Response surface methodology was used to produce two response equations which, in turn, became goals for a goal programming model. This model provided optimal values for the decision variables in order to achieve manning and experience-level goals. Keywords

Surface Launched Air Missile

Thesis Advisor: Major Kenneth W. Bauer, PhD
            Associate Professor of Operational Sciences

Approved for release in accordance with AFR 190-1
JS Proenwerid

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Kenneth W. Bauer, Major, USAF	513-255-3362	AFIT/ENS

DD Form 1473, JUN 86   Previous editions are obsolete.